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THESIS

SPATIAL VARIABILITY OF THE AMBIENT NOISE FIELD ASSOCIATED WITH THE MARGINAL ICE ZONE AND ITS RELATIONSHIP TO ENVIRONMENTAL PARAMETERS

by

Kristian Pedersen Biggs

December 1988

Thesis Advisor: Dr. Robert H. Bourke

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During the month of July 1987 an acoustical experiment was conducted by the United States Naval Research Laboratory (NRL) in the East Greenland Sea Marginal Ice Zone (MIZ). Ambient noise "hot spots" or concentrated areas of relatively high noise levels were found along the ice edge using a towed array. Ambient noise levels were obtained on 27 and 28 July using AN/SSQ-57A and AN/SSQ-57XN5 calibrated sonobuoys. The temperature structure of the area was determined using XBT (ship) and AXBT (P3C aircraft) buoys placed inside and outside the ice edge. The ice edge was determined from coincident satellite photos, 90 GHz microwave imagery and P3 radar ice edge maps. Weather data (sea state and wind speed and direction) were recorded on the ship. The data seem to indicate a correlation between the high ambient noise levels of the hot spots and the presence of a large topographically controlled mesoscale eddy located at the southeastern extent of the MIZ.

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Spatial Variability of the Ambient Noise Field Associated with the Marginal Ice Zone and Its Relationship to Environmental Parameters

by

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Lieutenant, United States Navy
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ABSTRACT

During the month of July 1987 an acoustical experiment was conducted by the United States Naval Research Laboratory (NRL) in the East Greenland Sea Marginal Ice Zone (MIZ). Ambient noise "hot spots" or concentrated areas of relatively high noise levels were found along the ice edge using a towed array. Ambient noise levels were obtained on 27 and 28 July using AN/SSQ-57A and AN/SSQ-57XN5 calibrated sonobuoys. The temperature structure of the area was determined using XBT (ship) and AXBT (P3C aircraft) buoys placed inside and outside the ice edge. The ice edge was determined from coincident satellite photos, 90 GHz microwave imagery and P3 radar ice edge maps. Weather data (sea state and wind speed and direction) were recorded on the ship. The data seem to indicate a correlation between the high ambient noise levels of the hot spots and the presence of a large topographically controlled mesoscale eddy located at the southeastern extent of the MIZ.

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I. INTRODUCTION

The Arctic is a region of increasing interest to the United States Navy due its significant strategic value. Conducting Naval operations in this region requires an accurate knowledge of the environment and thus a primary goal of naval basic research in the Arctic is to develop a better understanding of Arctic processes [*Curtin*, 1988]. In July 1987, an acoustic experiment was conducted by the United States Naval Research Laboratory (NRL) as part of operation RESOLUTE SUPPORT in the Greenland Sea. The purpose of the investigation, the first of two planned experiments with the same objectives, was to identify and study local regions of high ambient noise levels or "hot spots" present in the marginal ice zone. An important aspect of the research was to examine the spectral characteristics of the hot spots by combining real time acoustic processing of the ambient noise with advanced remote sensing of the environment [*NRL proposal*, 1987].

A marginal ice zone (MIZ) is a transition region from open ocean to pack ice where interaction between polar and temperate climate systems result in an edge of ice cover with strong horizontal and vertical gradients in the atmospheric and oceanic variables [*Johannessen et al.*, 1983]. Hot spots, concentrated areas of relatively high ambient noise levels, have been shown to exist in the vicinity of the ice edge [*Yang et al.*, 1987]. The hypothesis proposed to explain these local noise sources is that they are associated with mesoscale eddies embedded along the ice edge and are generated by two fundamental mechanisms: 1) collisions and crushing of ice floes in regions of eddy convergence and 2) breaking of ice floes in regions of eddy divergence [*NRL proposal*, 1987].

This thesis is the first comprehensive analysis of the data resulting from the first experiment. The second experiment was originally scheduled for Spring 1988, with the author to be intimately involved in the collection of data, but unfortunately the experiment had to be postponed until 1989. It will include more extensive data collection due in part to the lessons learned from this research and serve to validate the 1987 experimental results. Due to the time constraints involved in the completion of this thesis, the analysis presented herein is not meant to be final, but to serve as an in-depth preliminary look at the available data as well as data collection procedures. Hopefully, this will be beneficial to the planning, execution, and evaluation of the second experiment.

II. BACKGROUND

A. PHYSICAL OCEANOGRAPHY

The Greenland Sea is a very complex acoustic environment that until recent years had not received substantial attention from the scientific community. Thanks primarily to the Marginal Ice Zone Experiment (MIZEX) program, an Office of Naval Research (ONR) Arctic Sciences Program Accelerated Research Initiative (ARI) of five year duration [*Curtin*, 1988], the knowledge base has increased significantly. This is readily apparent from the number of recent papers appearing in scholarly journals [see e.g., *J. Geophys. Res. 92(C7), 1987*] and technical reports.

In order to better understand the relationship between eddies in the marginal ice zone and the resultant ambient noise, it is necessary to first briefly examine the physical oceanography of the Greenland Sea. This overview will focus on the primary features of the bathymetry and circulation, the water masses, the ocean frontal systems, and the marginal ice zone. The circulation in the Greenland Sea is dominated by a large cyclonic gyre formed by the southward movement of Polar Water (PW) from the East Greenland Current (EGC) north of Jan Mayen Island, the eastward flowing Jan Mayen Polar Current, and the northward and westward movement of part of the Atlantic Water (AW) in the north Greenland Sea [*Johannessen*, 1986]. *Aagaard* [1970] has shown that the gyre is forced by the wind stress over the Greenland Sea but noted that thermohaline effects were also important. In addition, the circulation and distribution of the water masses is known to be strongly affected by the bottom topography [*Johannessen*, 1986; *Gascard et al.*, 1988], e.g., the East Greenland continental shelf and a combination of fracture zones as seen in Figure 1.

A representative temperature profile from outside the ice edge and its corresponding sound speed profile are shown in Figure 2. They are typical of cold Arctic water augmented with summer surface heating which results in a shallow sound channel axis. In general, the sound channel axis depth varies from 0 to about 100 m east of the ice edge. Under the ice and in the open sea in winter, the acoustic channel axis is at the surface producing the well-known "half-channel" (Figure 3). The major variation of axis depth is found along the Jan Mayen, Mohns, and Knipovich ridges as the axial depths rise from the southeast to northwest side of the basin. These locations are portrayed in Figure 4.

Figure 5 shows the locations of the major fronts found in the Nordic Seas. These fronts are often anchored by bottom features such as continental shelf edges and midbasin ridges [*Triantos and Hurdle*, 1987]. The one of most significance to this experiment is the East Greenland Polar Front (EGPF). In summer it has a strong horizontal temperature gradient which on its cold water side rapidly brings the sound speed axis to

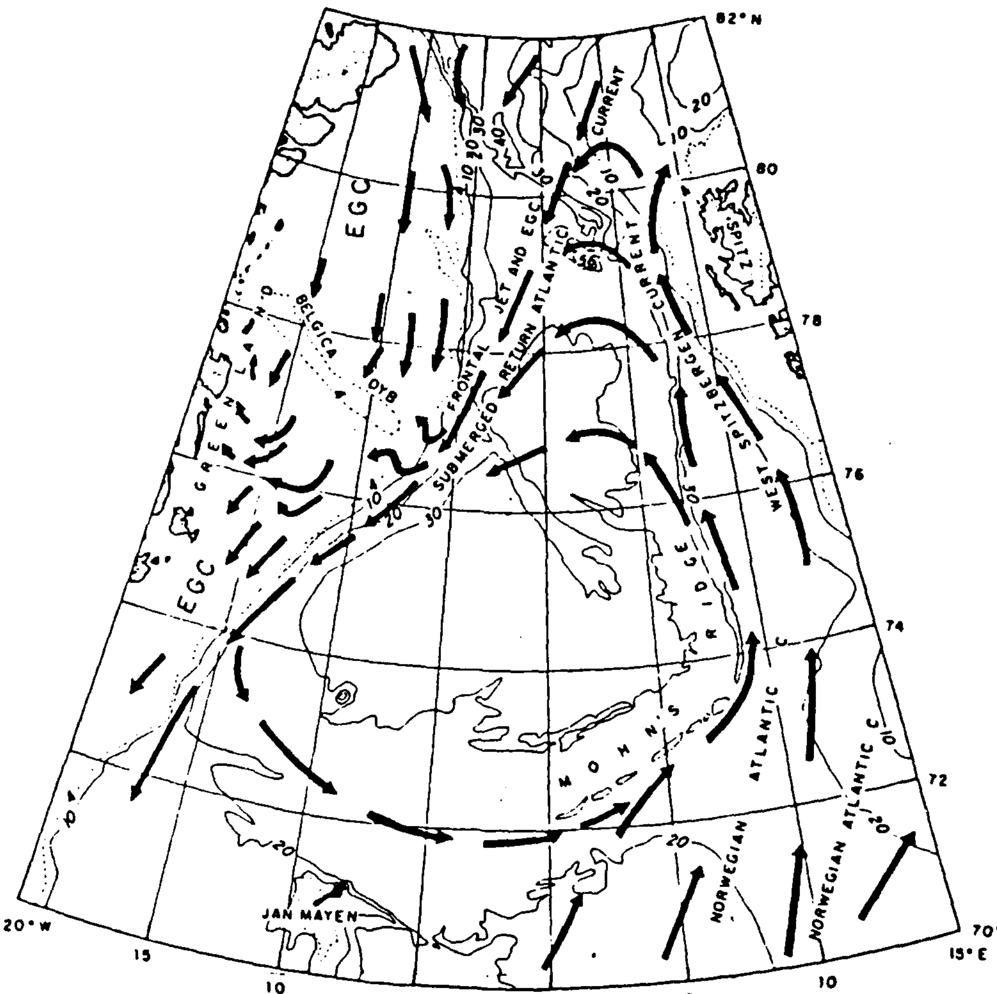


Figure 1. A map showing the general bathymetry (in units of 100 m) and circulation in the Greenland Sea [from *Paquette et al.*, 1985].

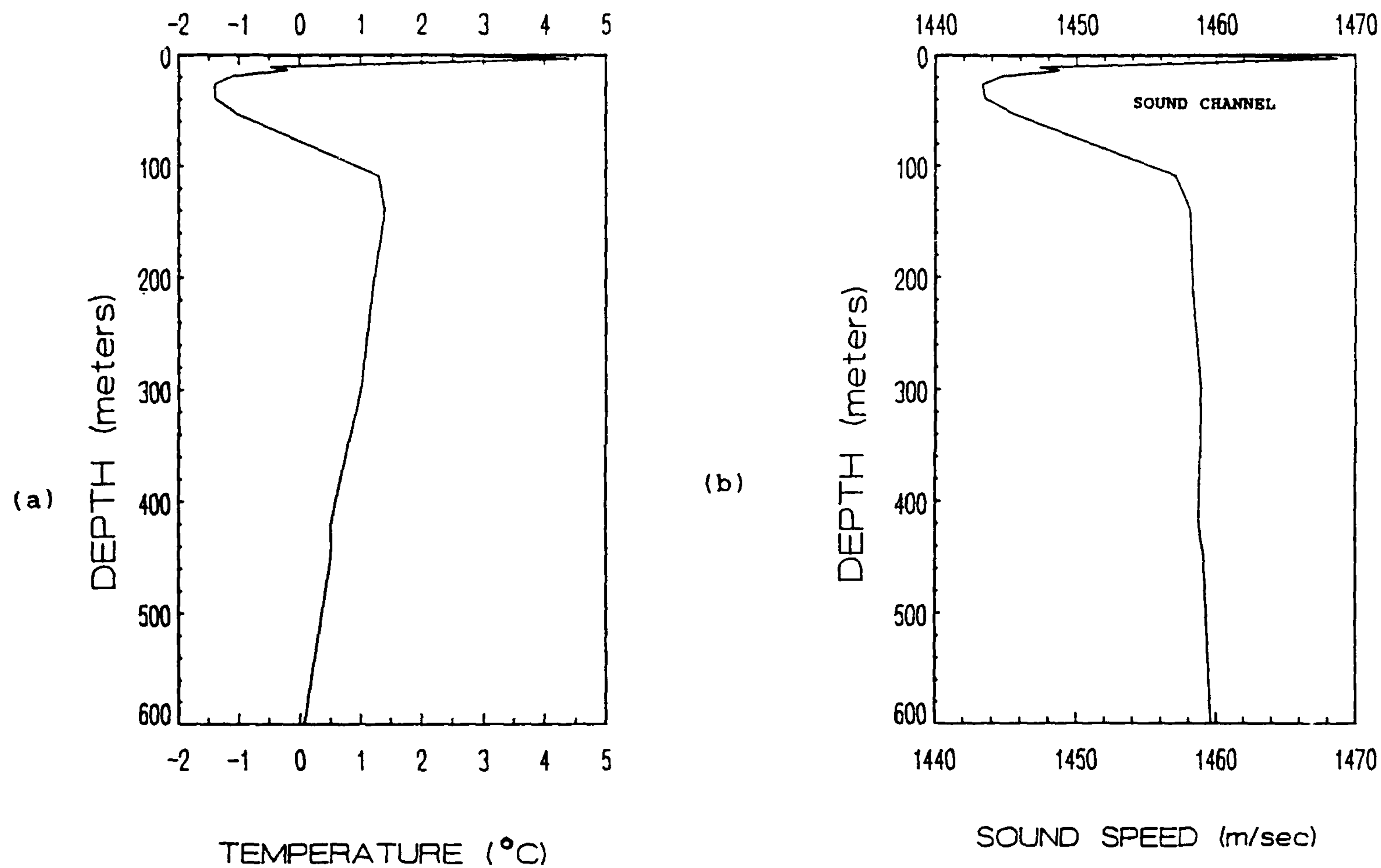


Figure 2. Typical profiles observed outside ice edge: (a) temperature profile from an XBT; (b) corresponding sound speed profile.

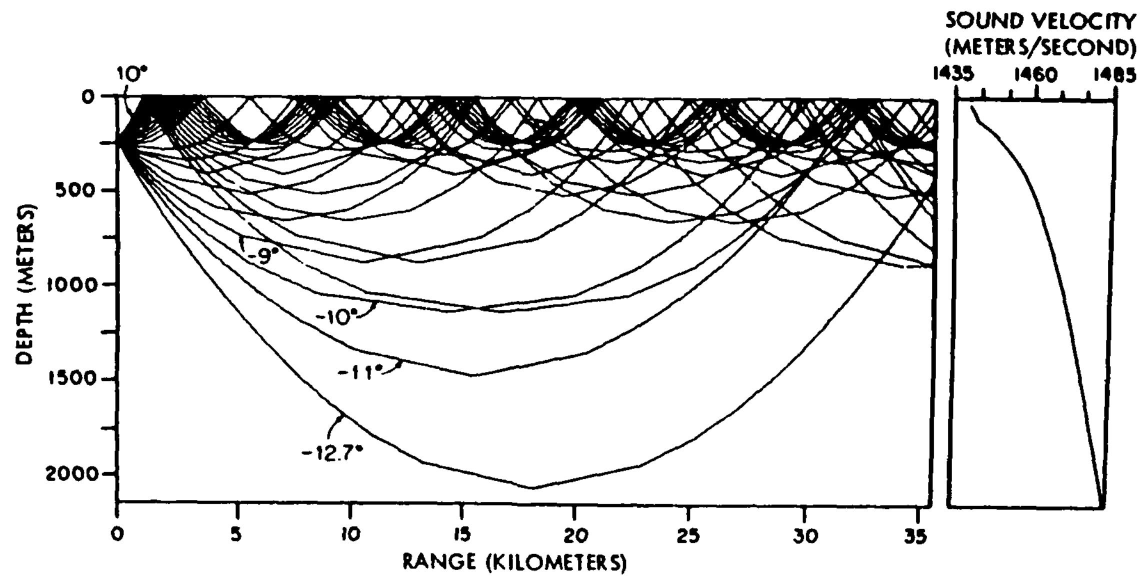


Figure 3. Typical sound speed profile and corresponding ray diagram for sound propagation in the Arctic Ocean [from *Urick*, 1986].

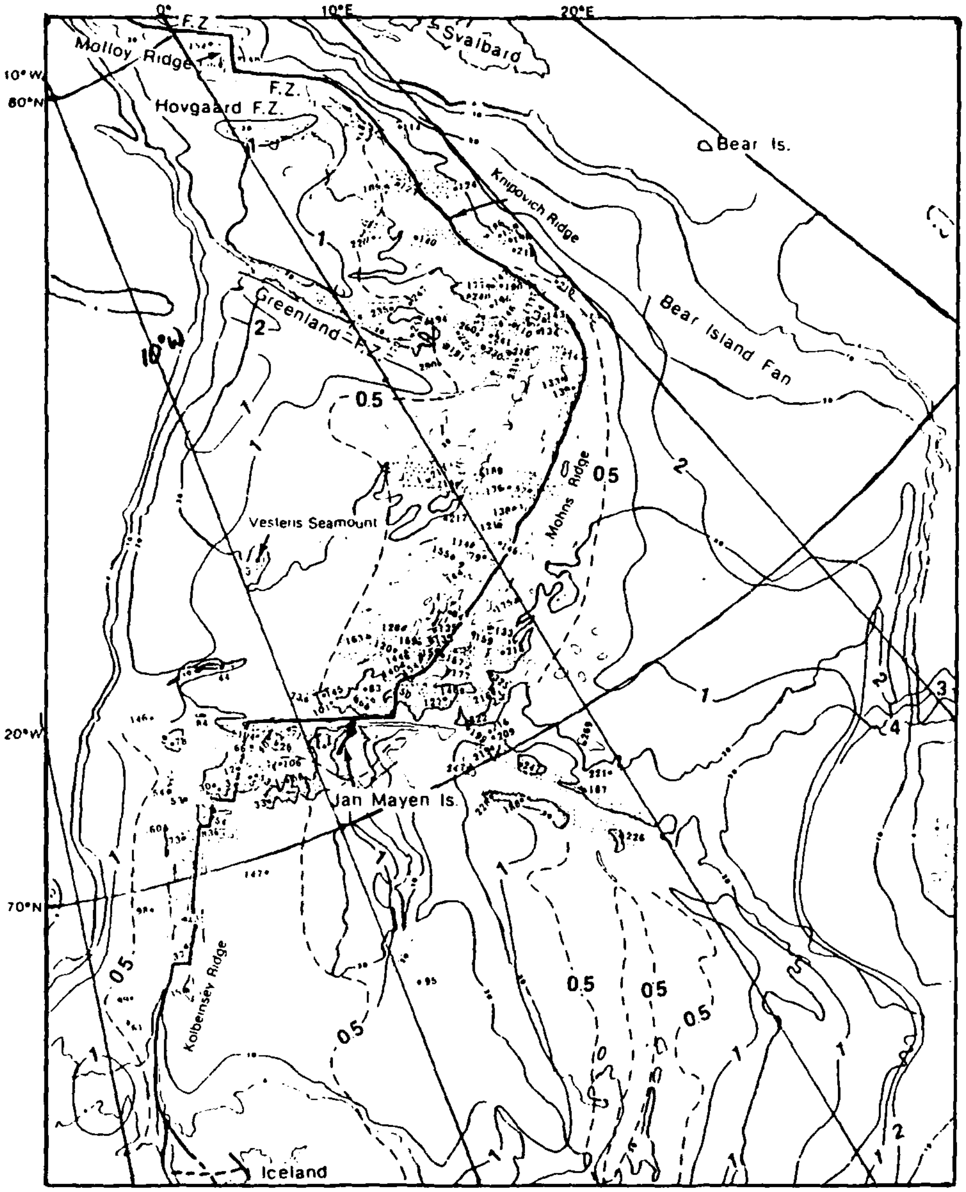


Figure 4. Bathymetry of the Nordic Seas (in hundreds of meters) and some minimum soundings (in tens of meters) [from *Perry*, 1986].

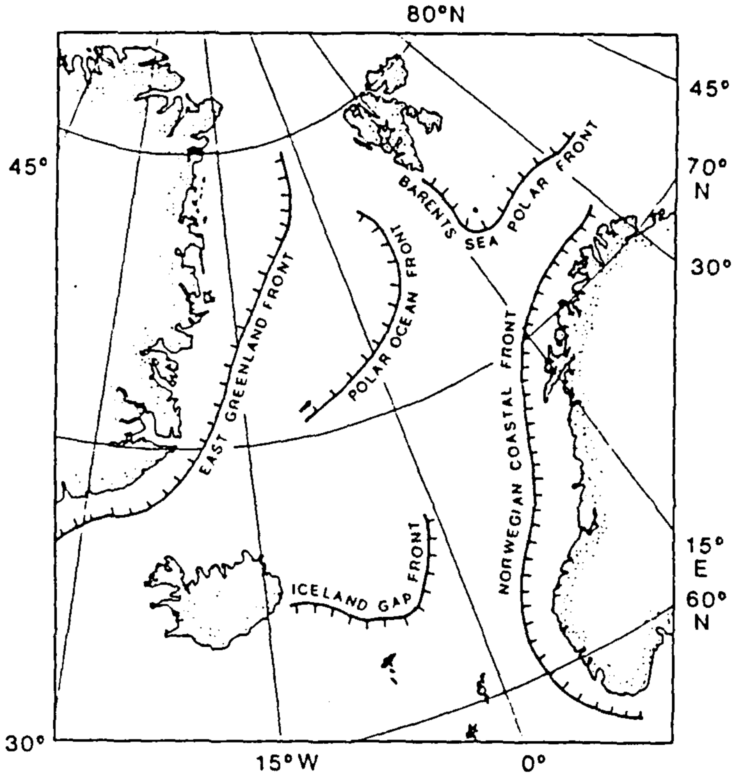


Figure 5. The major oceanographic fronts found in the Nordic Seas [from *Johannessen*, 1986].

the surface. This front strongly affects acoustic propagation of surface noise sources by ducting energy from a surface channel under the ice downward into a 1000 m thick channel with an axial depth of about 550 m. The EGPF coincides with the high speed jet of the EGC which has recently been shown to be quite narrow (approximately 25-40 km), resemble a dynamically stable jet, and closely follow the continental slope [*Gascard et al.*, 1988]. The continental slope is understood to be the region between the 1000 and 2000 m isobaths.

The marginal ice zone is a noisy, complex transition region which extends from the ice edge to the pack ice, about 100 km into the ice covered region. In winter most of the ice in the Greenland Sea is comprised of thick first-year ice and multiyear ice. During the summer and fall, the majority is new or first-year ice. *Gascard et al.* [1988] characterize the MIZ below 77°30'N in terms of <u>two</u> different limits between the pack ice and the open ocean. The first is the one at the sea-ice boundary which they term the outer limit and is commonly accepted to be the real ice edge. It is described as very diffuse in some places while being well defined by compacted small floes in others due to wind and swell resulting in a highly variable boundary. The second or inner limit deliniates the MIZ proper and the pack ice (ice concentration of 4/10 or greater) drifting in the EGC. It is more stable in location and more uniform than the outer edge but summer melting can reduce its sharpness. The MIZ between these limits is characterized by low ice concentrations, highly variable width, typical floe size (diameter less than 1 km), and eddy features. Breakup of floes due to wave action and lateral melting contribute to this low concentration and floe size distribution up to 60 km into the ice [*Gascard et al.*, 1988], but cannot account for the inner limit. They conclude that the inner limit must be related to the strong shear existing between the EGC central flow, where Arctic ice is moving southerly at speeds up to 1 kt, and the ice margin with its embedded mesoscale eddy circulation. During the month of July they observed strong eddy activity and a shift from northerly-northeasterly on-ice winds at the beginning of the month to southerly, off-ice prevailing winds late in the month.

Mesoscale eddies found at the ice edge are often characterized by a pair of ice-tongue systems. The southerly one is due to off-ice entrainment (W to E) directly associated with cyclonic eddy rotation while one to the north is due to a divergence area created upstream [*Gascard et al.*, 1988]. They reasoned that since the flow is basically quasi-irrotational, the velocity components wholly depend upon a velocity potential function. Thus an area characterized by intense acceleration such as is encountered near eddies should be counterbalanced by an area of deceleration and divergence to satisfy continuity. The eddies advect warm Atlantic Water westward beneath the ice (transporting heat into the MIZ) and pull ice and Polar Water away from the ice pack into the warm AW. These features can often be observed by aircraft or remote sensing techniques. After ruling out the possibility of the EGC to self-generate ice-edge eddies, *Gascard et al.* [1987] found the interaction of westward propagating open ocean eddies from the West Spitsbergen coast with the EGC to be the prime eddy generating mechanism instead of fourth in the hierarchy of five sources given by *Johannessen et al.* [1987].

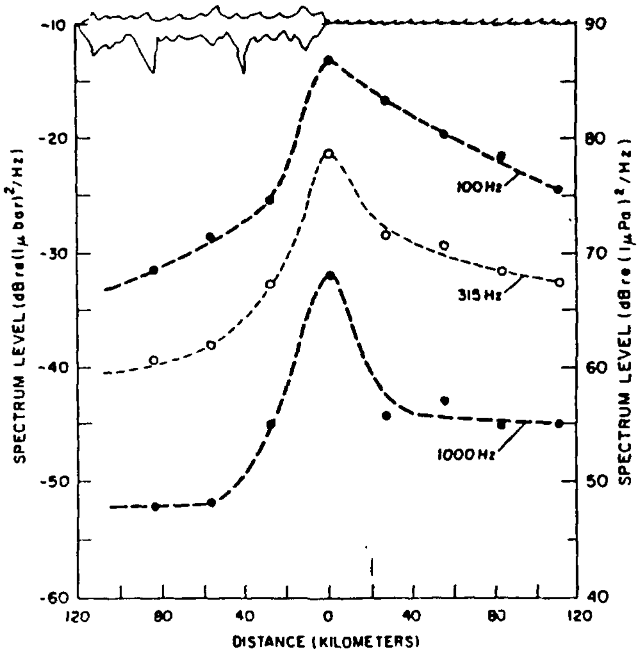
B. AMBIENT NOISE

Ambient noise is the prevailing, sustained, unwanted background noise of the ocean. Ambient noise excludes self noise, electrical noise, and momentary sounds such as that of a nearby ship or biological organism (e.g., whale) [*Urick*, 1986]. In essence, it is the remaining noise after all other noise sources have been eliminated. An excellent introduction to the topic of ambient noise, which includes material from a great number of ambient noise studies (through 1986), can be found in *Urick's* book, <u>Ambient Noise In the Sea</u> [1986].

Interest in the acoustic properties of the MIZ has increased manifold since the early 1970's when Diachok and Winokur focused their attention on the study of ambient noise along the Arctic ice/water boundary [*Diachok and Winokur*, 1974]. Their significant finding was that ambient noise levels peaked at the ice/water boundary of the MIZ when compared with levels under the ice and in open water. They showed that this peak was relatively sharp for a compact ice edge, becoming broader as the ice edge becomes more diffuse as illustrated in Figures 6a and 6b. Another feature evident in the two figures is the difference in the rates at which the ambient noise levels decrease with increasing distance from the ice edge. The levels under the ice fall off more rapidly than those in the open ocean. In addition to finding the ambient noise levels lower under the ice, they also found them to be intermittently spikey which was attributed to the collision and cracking of ice floes [*Diachok*, 1980]. Diachok concluded that sea-ice boundary-generated noise may be treated as a line source of sound at distances from the edge which are large compared to the magnitude of ice-edge irregularities [*Diachok*, 1980].

Recent investigations by NRL scientists [*Yang et al.*, 1987] have shown that at the ice edge ambient noise is sometimes concentrated in small areas or "hot spots" along the ice edge. A feature which distinguishes hot spot noise from standard sea noise is a 12 dB/octave rolloff from 100 to 500 Hz as opposed to a 6 dB/octave rolloff in the open sea. The following parameters are well known to affect ambient noise generation in the Arctic seas: sea ice kinematics (translation, vorticity, divergence, normal deformation, shear deformation); sea state; currents; eddies; winds; air temperature; and biologics [*NRL*, 1987]. The NRL scientists reported that they were unable to indentify the generating sources but

(a)



(b)

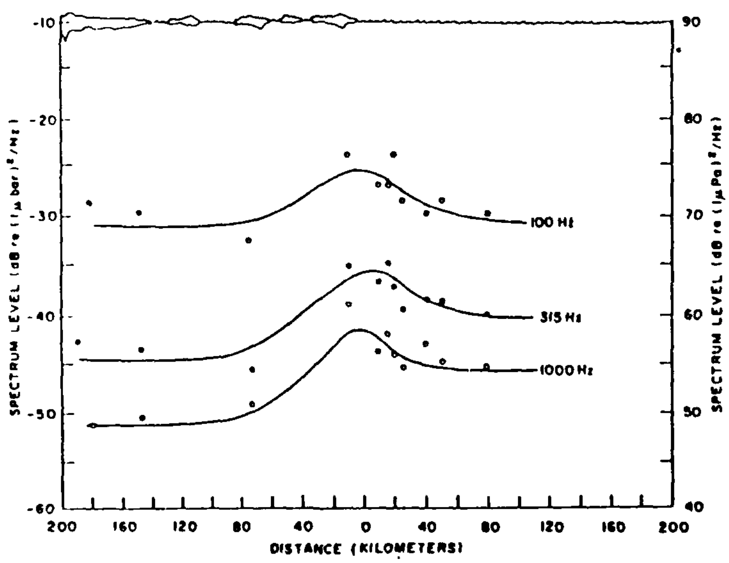


Figure 6. Variations of median ambient noise sound pressure spectrum levels with distance from the ice edge for frequencies of 100, 315, and 1000 Hz: (a) Compact ice edge with sea state 2; (b) Diffuse ice edge with sea state 1 [from *Diachok and Winokur*, 1973].

the nominal separation (50 km) and spatial extent (5 km) of the noise hot spots were the same dimensions as some of the eddies found in the Greenland Sea by *Johannessen et al.* [1983]. What was needed was an experiment which combined real time acoustic processing with advanced remote sensing techniques to identify the primary contributors to ambient noise hot spots at low frequencies. This was the motivation behind the experiment reported herein [*NRL proposal*, 1987].

III. DATA COLLECTION AND ANALYSIS

A. TYPES OF DATA

To support the objectives of the field program data were collected from three entities: the research ship, aircraft, and satellite. Personnel on the ship recorded weather observations, launched 47 expendable bathythermograph (XBT) devices, and obtained navigational data and "hot spot" locations. A US Navy P3C (II) aircraft deployed 18 AN/SSQ-57A and AN/SSQ-57XN-5 ambient noise monitoring buoys and 25 AXBT buoys. An NRL RP3A aircraft gathered 90 GHz microwave imager remote sensing information. Satellite AVHRR (Advanced Very High Resolution Radiometer) data consisted of infrared (IR) and visual depictions of the ice edge and sea surface temperature (synoptic) gradients.

B. DATA COLLECTION

1. Ambient Noise Data

Eight LOFAR sonobuoys (AN/SSQ-57A and AN/SSQ-57XN-5) were deployed on 27 July 1987 and ten on 28 July. LOFAR sonobuoys employ hydrophones which are omnidirectional in both the vertical and horizontal planes. The SSQ-57A is unique in that it is calibrated to allow accurate determination of ambient noise levels. The difference between a 57A and a 57XN-5 is that the latter has an operating depth of 1000 ft (305 m) whereas the former has a maximum depth of 400 ft (122 m). The ambient noise data were collected on board P3C aircraft equipped with AN/ARR-72 receivers and a 28-track analog, FM wideband group II (WBII) tape recorder. The tape speed for 27 July was 3-3/4 ips and 7-1/2 ips for 28 July.

The ship, directed toward regions of high ice concentration by the aircraft and towing an acoustic array of 32 hydrophones, moved parallel to the mean ice edge. If the ice edge acted as a continuous line source of constant source level, the noise would be distributed across many beams of the array. If, however, the ice edge noise was concentrated in localized "hot spots", then a peak would be evident in a small number of dominant beams [*Yang et al.*, 1987]. The latter was found to be true and standard localization techniques were employed to fix the location of the hot spots. The array was used only to locate the hot spots. That is, the ambient noise analysis in this thesis does not include any array data.

The buoys were deployed in pairs with one shallow (60 ft) and one deep (300 ft or 1000 ft) in the vicinity of the hot spots. There were originally three data tapes, one for 27 July and two for 28 July. Unfortunately, only the first of the two tapes for 28 July was retrieved after the experiment and thus some of the ambient noise data collected was not available for analysis. Figure 7 shows the location of the ambient noise buoys in relation to the hot spots and radar ice edges for 27 and 28 July.

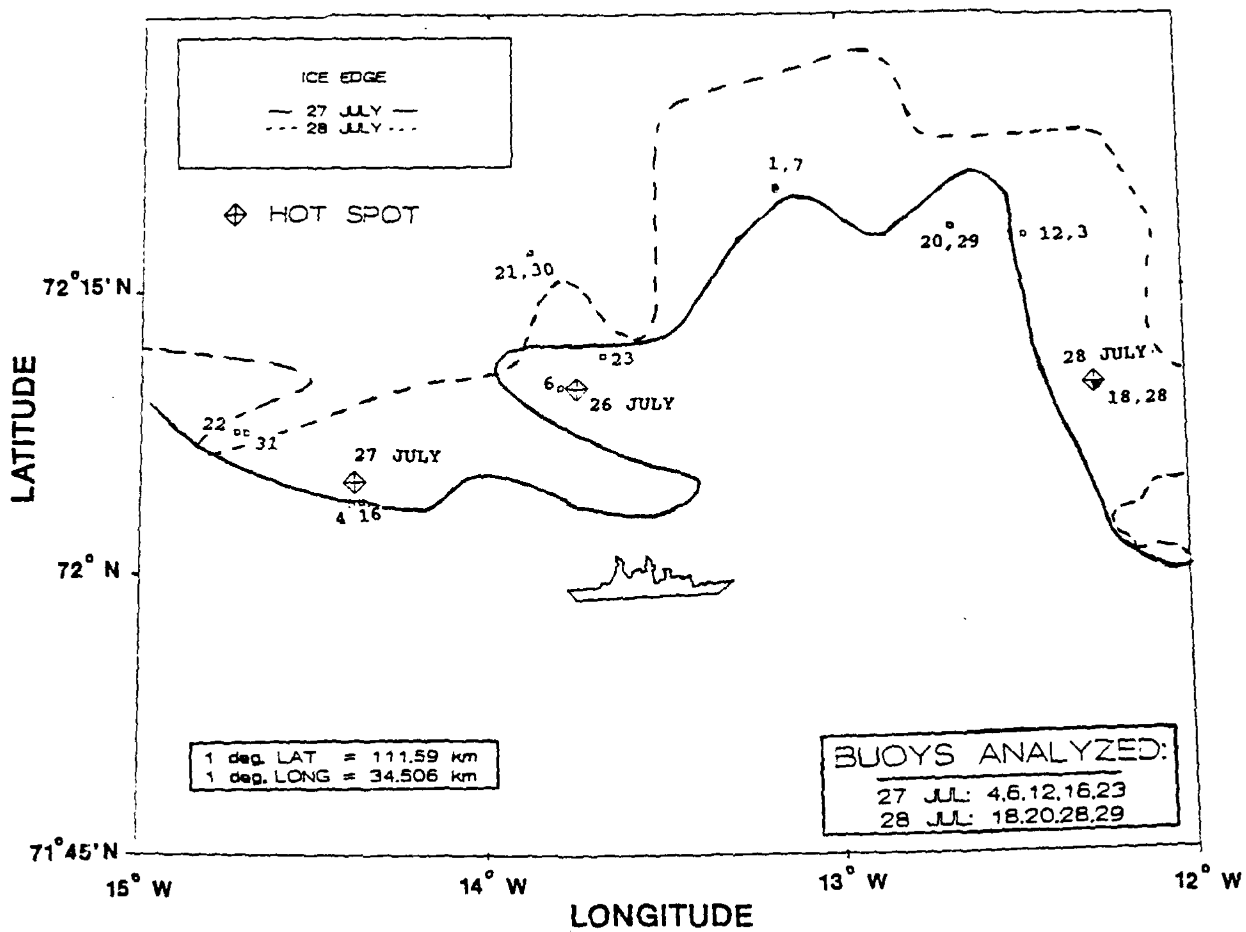


Figure 7. Ambient noise buoy and hot spot positions relative to the radar ice edges of 27 and 28 July 1987. The hot spot for 26 July is included as well. Some of the buoys were not analyzed (see text).

2. Bathythermograph Data

Fifteen Airborne Expendable Bathythermograph (AXBT) buoys (AN/SSQ-36) were deployed on 27 July and ten on 28 July. Additionally, the ship deployed XBTs at midnight and every two hours between 0600 and 1800 on 24, 25 and 26 July. On 27 July, a total of 12 were expended (additional buoys expended between 1200 and 1800). Eight were deployed on the 28th. Figure 8 shows the locations of the XBT and AXBT buoys in relation to the hot spots and radar ice edges.

3. Weather Data

Wind speed and direction and sea state were recorded every two hours from 24 July to 29 July by personnel on board the research vessel.

4. Remote Sensing/Satellite Data

An NRL RP3A equipped with a 90 GHz microwave radiometry imager flew over the study area on 25 July and 28 July. AVHRR satellite data consisting of visual and (IR) imagery was collected from 24-27 July. Radar maps of the ice edge were made by ice observers on 27 and 28 July as shown in Figures 7 and 8.

C. DATA ANALYSIS

1. Ambient Noise Data

The 28-track tapes containing ambient noise and AXBT data were converted to 14-track tapes by Commander Task Group 168.2 in Norfolk, VA because a 28-track recorder was not

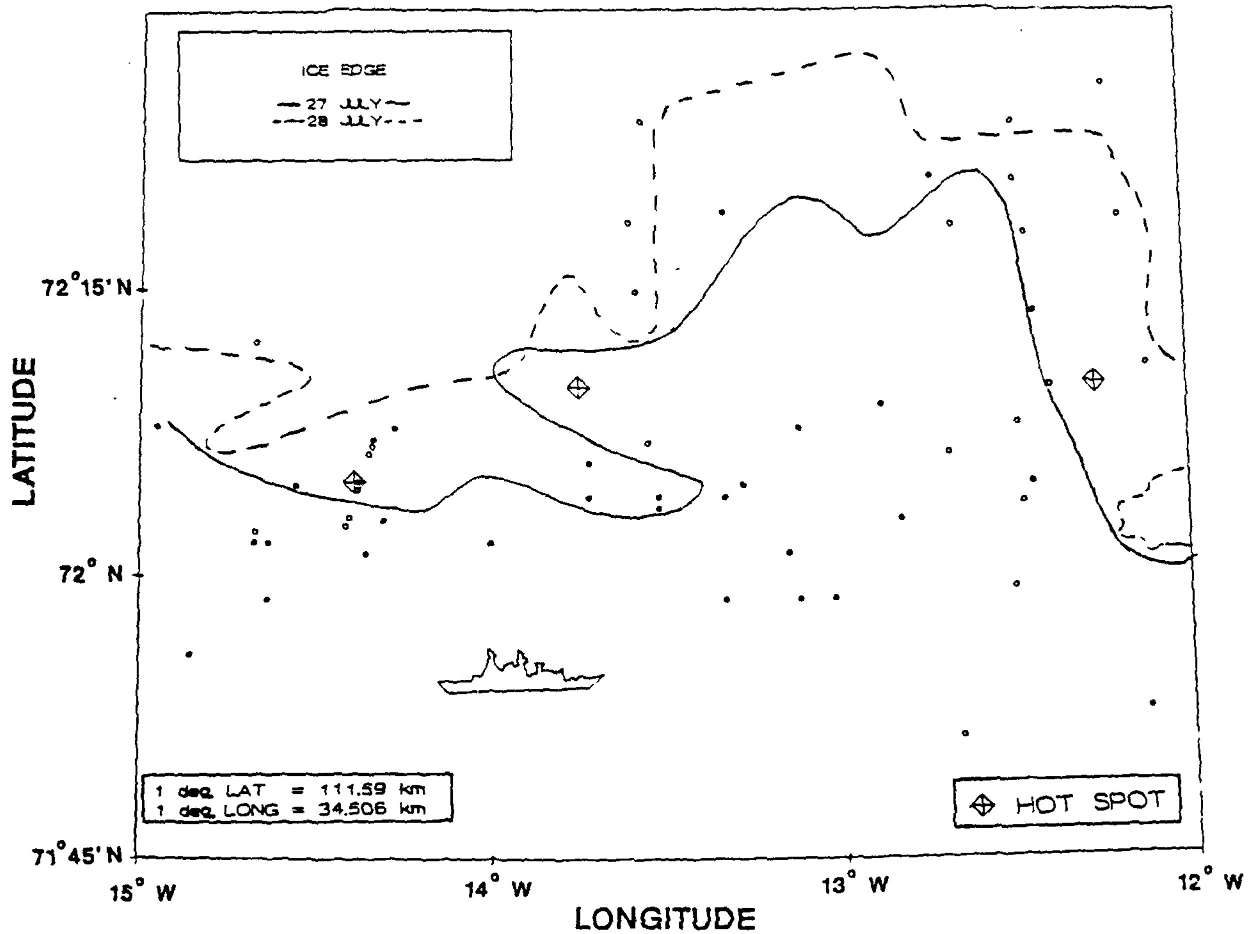


Figure 8. AXBT, XBT, and hot spot positions relative to the radar ice edges of 27 and 28 July 1987. The open circles indicate AXBTs while the filled circles indicate XBTs deployed from the ship.

available at the Naval Postgraduate School (NPS). A Honeywell 5600E Intermediate Band (IB) tape recorder was used to replay these tapes after performing initial calibration procedures. The Honeywell 5600E had only two available speeds: 7-1/2 ips and 15 ips. Since the 27 July tape was recorded at 3-3/4 ips, it had to be replayed at double speed. The 28 July tape was played back at the recorded speed of 7-1/2 ips. An intermediate band (IB) recording at 3-3/4 ips has a frequency bandwidth of only 1250 Hz while an IB recording at 7-1/2 has a bandwidth of 2500 Hz. The time code on the 27 July tape was not usable. This was true for the first copy of the 28 July tape as well. However, a 28 July tape with a usable time code and eight channels (as opposed to four) of ambient noise data arrived on 15 November 1988, too late to be of use in this thesis.

The hard copy gram analysis records (flight grams) were used to determine what sonobuoy data was on each channel of the tape and at what times since the grams were hardwired to the recorder channels. Thus while different buoys could be on the same tape channel, a single gram was always associated with one particular channel of the tape. The grams were not as completely annotated as desired but after some effort a tape map was made delineating what was on each channel of the tape at any given time.

Since a time code was not available, another means of determining times on the tapes was needed. The solution was to select a channel with a known AXBT trace (easily identified on the gram), replay that channel from the beginning while listening for the start of the first AXBT and then to use it as a common reference point. The tape footage counter index at this tape position was assigned the AXBT time. It was then relatively easy to determine times and corresponding tape index values from a knowledge of the number of feet of tape travel and the tape speed. This procedure worked quite well. The tapes were played back many times before formally processing them to select an interval free of RF interference, signal loss or anything else that would adversely affect processing. After the channels and their start/stop points had been identified using the times on the grams, the tapes were ready to be processed. Figure 9 shows the basic equipment configuration.

A Spectral Dynamics Model SD375 Dynamic Analyzer II was used to analyze the sonobuoy data. This versatile instrument is a stand-alone, hard-wired, dual channel microprocessor-based FFT analyzer and signal processor that analyzes frequencies up to 100 kHz with 400-line per channel resolution. An NEC APC IV personal computer (IBM/AT compatible) equipped with a National Instruments GP-IB interface card and software was used to control all aspects of the data acquisition process. The control program was written specifically for this thesis in Microsoft QuickBasic 4.0. The complete program listing is included as Appendix A.

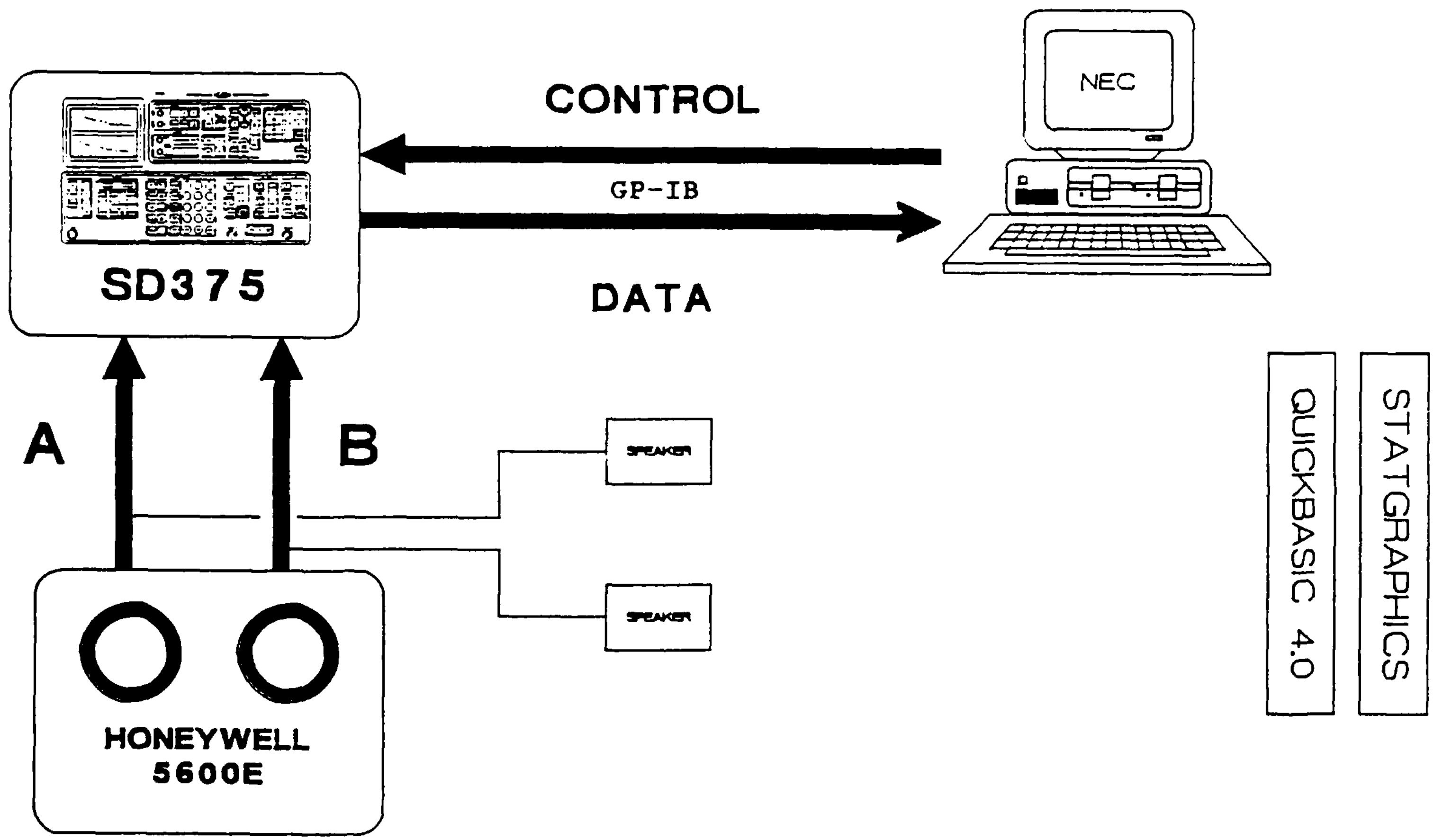


Figure 9. Equipment configuration for computer-controlled acquisition and analysis of data recorded on 14-track magnetic tapes.

After the descriptive information about the two channels, the frequency (frequencies) of interest and start time were entered, the tape was started (manually) and data acquisition begun. The sonobuoy data were linearly averaged for a period equal to 1 minute of real time data which equated to a 30 second processing interval for the 27 July tape and a 60 second interval for the 28 July tape. One minute averaging was chosen to average out the many temporary fluctuations and transients common to an ocean environment as well as to enhance identification of a persistent noise source or signal. The overall ambient noise power spectrum level was desired and not the spectra associated with transients.

Hanning window amplitude weighting, chosen to minimize the effect of the window function on the analysis and a standard choice for ambient noise power spectral analysis, and maximum overlap processing (the default for any frequency span greater than 1 kHz) were used. The window function dramatically reduced the sidelobe structure but had the unfortunate consequence of widening the resolution bandwidth (BW). For the Hanning window, the resolution bandwidth was computed from [*Instruction Manual*, 1981]

$$BW = (\text{Frequency Span}/400)*1.5.$$

Three different analyzer configurations were used as illustrated in Table I. Setups 1 and 2 were used to analyze the 28 July data. Two entirely separate analyses of the same section of the tape were done for the purpose of comparing the

Table I. SD 375 OPERATING PARAMETER SUMMARY

	Setup 1	Setup 2	Setup 3
Weighting	Hanning	Hanning	Hanning
Frequency Span	0-2 kHz	0-400 Hz	0-4 kHz
Averaging	Linear	Linear	Linear
Average Time	60 sec	60 sec	30 sec
Input Level	2 Vrms	2 Vrms	1 Vrms
Effective BW	7.5 Hz	1.5 Hz	15 Hz
Sample Rate	5.12 kHz	1.024 kHz	10.24 kHz

ambient noise levels obtained using different frequency spans and thus resolution bandwidths. Setup 3 was used to analyze the 27 July data. Its frequency span and sampling rate were double that of Setup 1 to account for the frequency doubling resulting from playback at twice recorded speed. The averaging period was one-half of the Setup 1 value so that 1 minute of real time data would be represented by each sample. This produced basically identical processing of the two tapes even though they were recorded at different speeds. The sample rate was fixed at 2.56 * Frequency Span. Anti-aliasing filters were selected automatically by the SD375 on each channel for each frequency range with initial 120 dB/octave rolloff for 70 dB rejection of anti-aliasing terms [*SD375 User's Manual*, 1982].

The computer checked the SD375 continuously near the end of the averaging interval until it detected that averaging was complete. The SD375 then transmitted the precision data contents of its averager memory to the computer's random access memory (RAM) using ASCII byte coding which took about three seconds to complete. Immediately after receiving the data, the computer reset the averager memory and started the next sample. This ensured maximum utilization of the relatively small amount of useful data on the tape. Next, the channel A and channel B data were written to separate files on the computer's hard disk. The control phase of the computer program terminated when data sampling was stopped (manually) at the previously selected time.

The remainder of the computer program handled file conversion. The ASCII files were converted to random access numeric files with one real number for each of the 400 bins. Finally, this number became the actual value of the averager memory for a single bin when multiplied by the input level selected (full scale value) and divided by 451 (the gain factor for a Hanning window [*Instruction Manual*, 1981]).

The above procedure was repeated for each record in the input (ASCII) file resulting in a random access file containing 400 values for each sample conducted. To be useful this file needed to be subdivided into smaller files, one file for each sample. The program converted the random access file into ASCII files containing 400 records, one record for each bin. In addition, an interactive file conversion subprogram created similar files for each frequency requested. These frequency files contained the values for a particular frequency from all of the samples.

The statistical analysis of the data was accomplished with *STATGRAPHICS* [1988] statistical software. The files generated were imported directly into the program. Each file was converted into a variable array and all the arrays for a particular channel were grouped into a common file. The magnitude values were then transformed into corrected power values (from volts to dB re $1uPa^2/Hz$).

Mathematically, this transformation was as follows:

$$P = 20*LOG(M/1volt) - 10*LOG(BW) + C(f)$$

where P is the ambient noise level (power) in dB re $1uPa^2/Hz$, M is the magnitude of each bin in volts, BW is the effective bandwidth of each bin and C(f), a function of frequency only, is the correction for each bin frequency which relates dB re $1V^2$ to dB re $1uPa^2$. The standard sonobuoy calibration curve, with a published uncertainty of ±2 dB, used to determine the values of C(f) was provided by NRL [*Gruber,* 1988] but is classified and therefore will not be discussed in this thesis. There is an additional correction term, not shown in the above equation, involved which accounts for the receiver calibration. This term was omitted because it was unable to be determined from the data tapes. That is, known calibration tones were not available for each channel. This has an obvious effect on the accuracy of the results. This correction is assumed to be constant with frequency (commonly done since only one frequency of known amplitude is usually used) [*NRSC*, 1988]. If the reference value of 1 volt was actually 1.1 volts, then this would amount to a correction of -0.8 dB. That is, the true value would be 0.8 dB lower than the values reported herein.

The individual spectra of each sample were averaged to create a mean spectrum for each buoy during the time frame investigated. Averaging was performed on the magnitude data to preclude errors due to nonlinearities from entering into the data analysis. These mean magnitude data were then transformed into corrected mean power spectra in the method described above and plotted. The mean power spectra for each buoy is included in Appendix B.

A more descriptive and statistically sound analysis was performed by determining the 50th percentile value (median) of all the values in the set of samples for each frequency of interest. The spread in the ambient noise measurements at each frequency was determined from the difference between the 90th and 10th percentiles. By working with the median vice average value, dramatic shifts in the magnitudes of a few samples would not have undue influence on the value sought to be the most representative of the data set.

2. Oceanographic/Environmental Data

a. Bathythermograph Data

As an aid to making comparisons between the ambient noise levels of different buoys, a knowledge of the local environmental differences in the conditions pertaining to each buoy is very important. For this reason temperature contour plots (Figures 10, 11, and 12) were drawn for depths of 16, 33, and 60 ft (5, 10, and 18 m), respectively. The 60 ft depth corresponds to the depth of the shallow buoys. The deep buoys on 27 July were placed at 1000 ft while on 28 July they were located only 300 ft below the surface. All XBTs were treated synoptically, i.e., as if they were expended at the same time.

b. Weather

The wind speed and direction and sea state recorded every two hours were plotted (Figures 13 and 14) to determine not only the conditions which existed during the time frame of sonobuoy data acquisition but also to examine how these conditions changed over time. Table II is a summary

Table II. WEATHER DATA SUMMARY

	24 July	25 July	26 July	27 July	28 July
Sea State	0-1	1-4	1-3	1-2	0-1
Wind Speed (*kts*)	4-8	3-20	6-10	5-15	0-4
Wind Direction (°T)	280	220	240	275	230

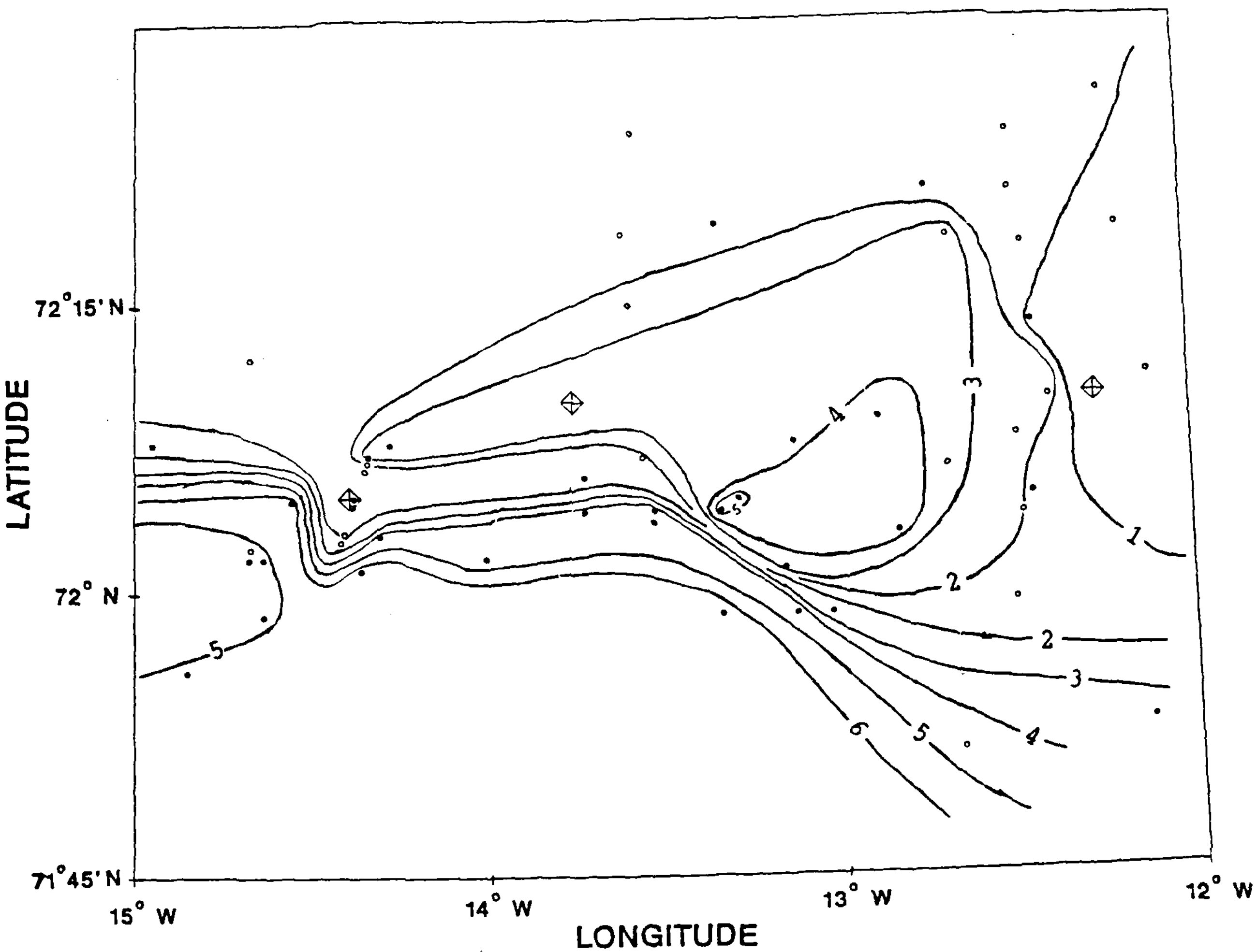


Figure 10. Temperature contours (°C) at a depth of 5 m from bathythermograph data showing BT and hot spot positions. The cold water tongue and large embayment of warm water are very distinct.

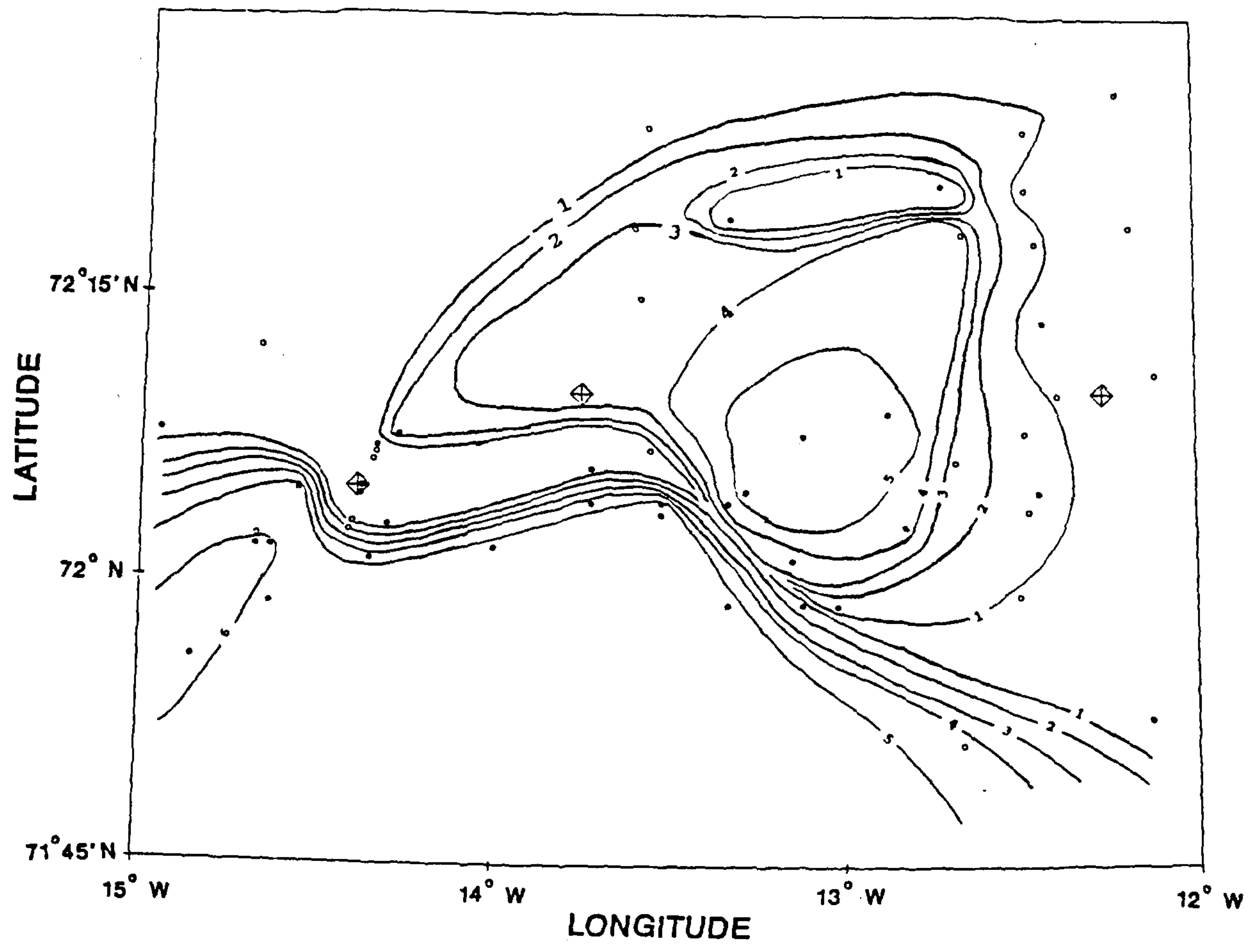


Figure 11. Temperature contours (°C) at a depth of 10 m from bathythermograph data showing BT and hot spot positions. The cold water tongue and large embayment of warm water are very distinct.

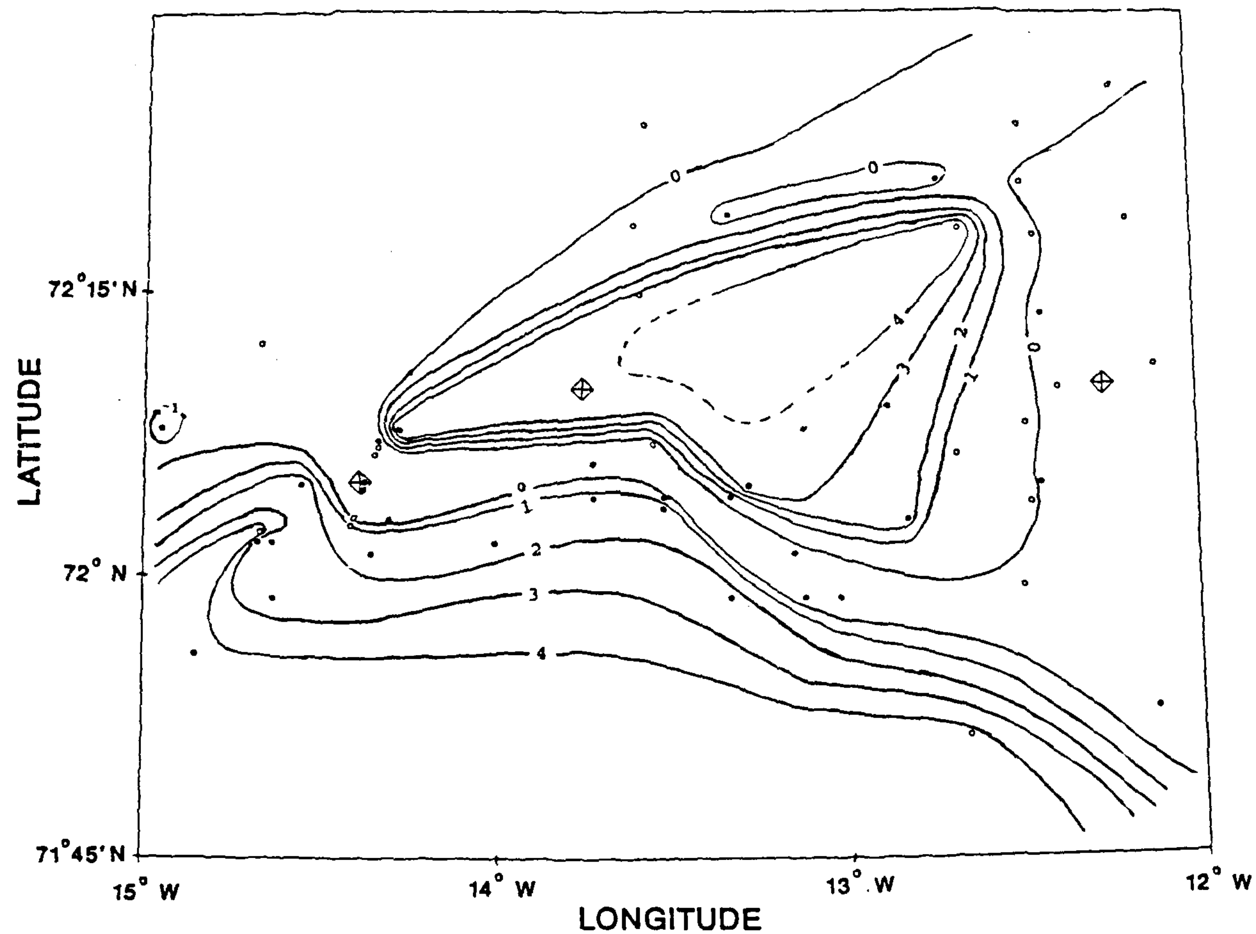


Figure 12. Temperature contours (°C) at a depth of 18 m (depth of shallow ambient noise buoys) from bathythermograph data showing BT and hot spot positions. The cold water path and large area of warm water are still distinct.

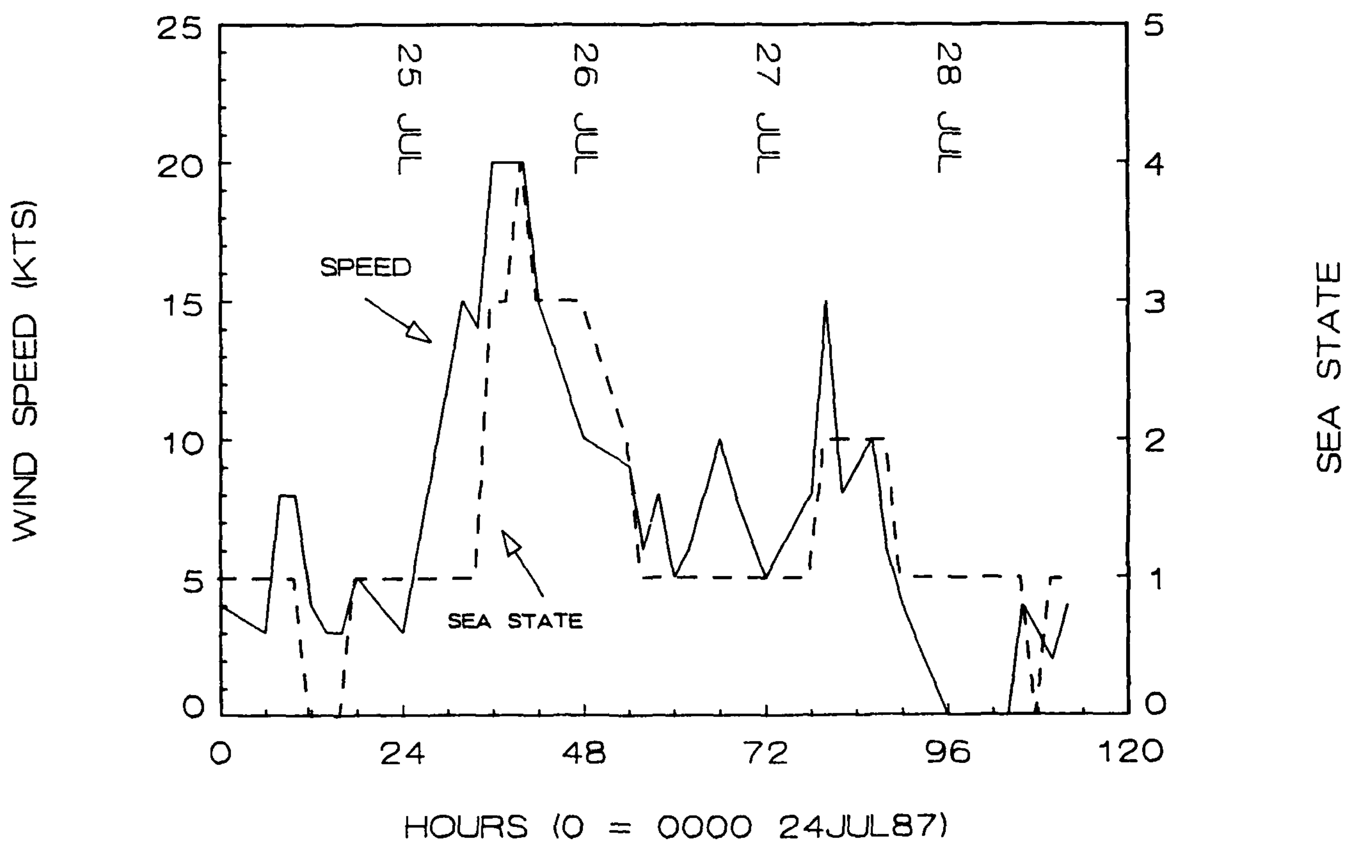


Figure 13. Wind speed and sea state recorded on the ship for the period 24 to 28 July 1987.

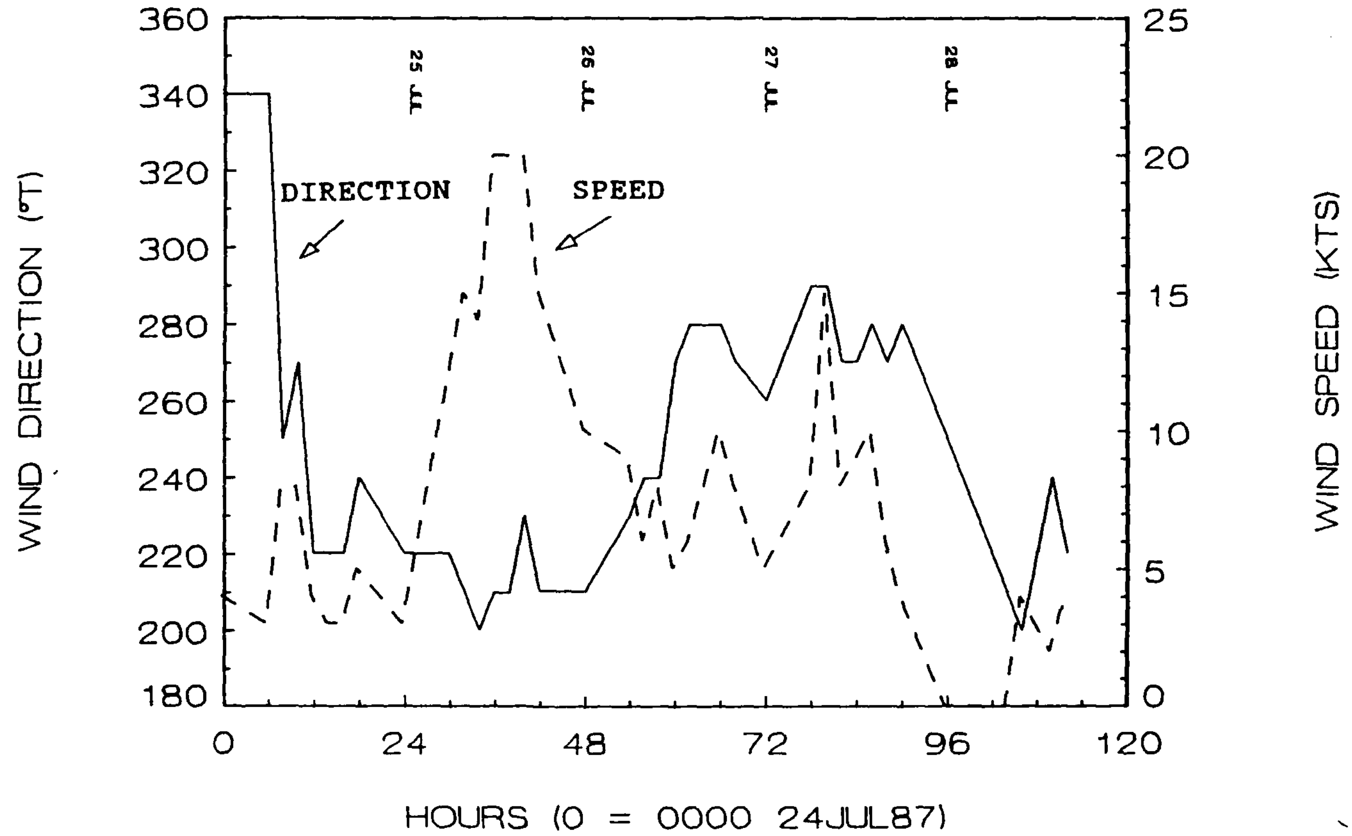


Figure 14. Wind direction and speed recorded on the ship for the period 24 to 28 July 1987.

of the range of conditions on 24, 25, 26, 27 and 28 July. These parameters have been known to fluctuate dramatically over relatively short periods of time.

c. Remote Sensing and Satellite Data

Radar maps of the ice edge were made by P3 personnel on 27 and 28 July. All of the 27 and 28 July ice edges appearing in the figures are based on these radar maps. Microwave radiometer imagery at 90 GHz was obtained from a high altitude ice-edge overflight by NRL's RP3A on 25 July. The effort on 28 July did not produce useable results. The satellite information was processed by NRL and forwarded to NPS. This consisted of: xerox copies of seven N9 satellite photos (5 visual and ? IR for the period 24-27 July); four transparencies made from the visual satellite photos which were enlarged and cropped to show the operational area (one for each day); and two color transparencies made from the IR photographs (24 and 25 July). The xerox copies can be found in Appendix C. The most comprehensive and useful information available was for 25 July. No satellite information was obtainable for 28 July. The 25 July color IR transparency was used to trace out the ice edge and surface temperature contours (Figure 15). Very much enlarged, the important portion of Figure 15 is shown in Figure 16. None of the satellite data items contained a latitude/longitude grid. This made it difficult to derive the exact position of the ice edge in relation to the sonobuoy and XBT positions from the satellite

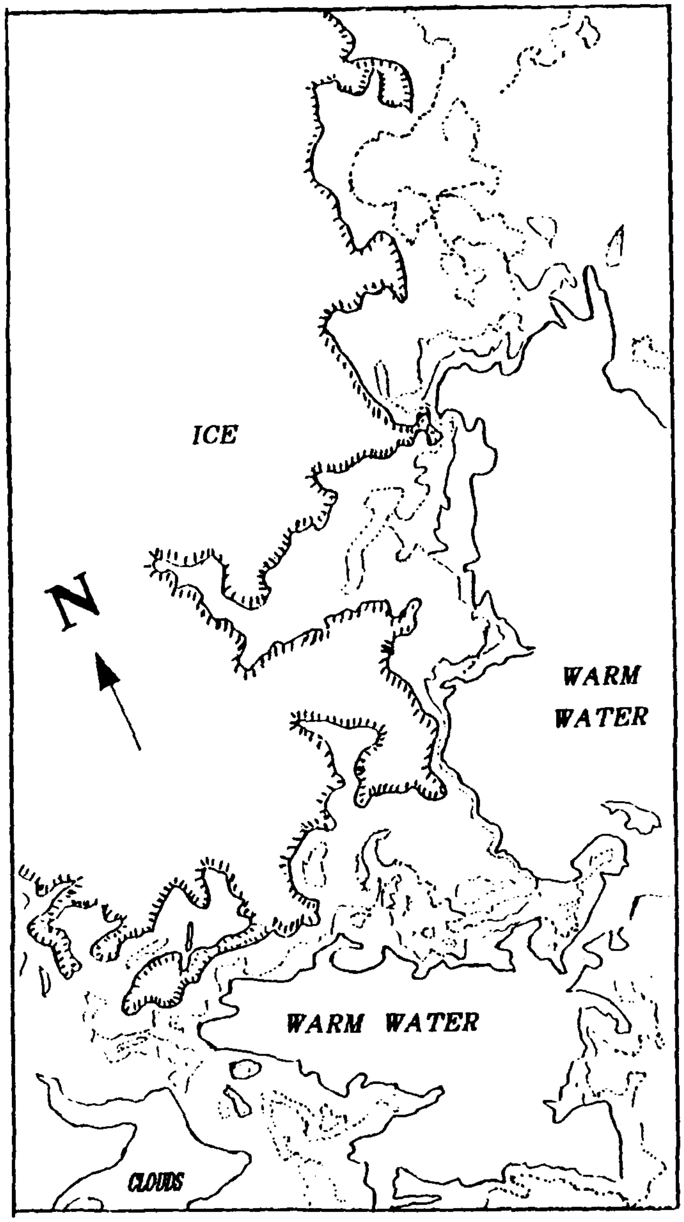


Figure 15. Sea surface temperature (SST) gradients extracted from a satellite color IR photo for 25 July 1987. The hatched line indicates the ice edge. The warm water is about 6°C. The satellite photo did not contain geographic coordinates.

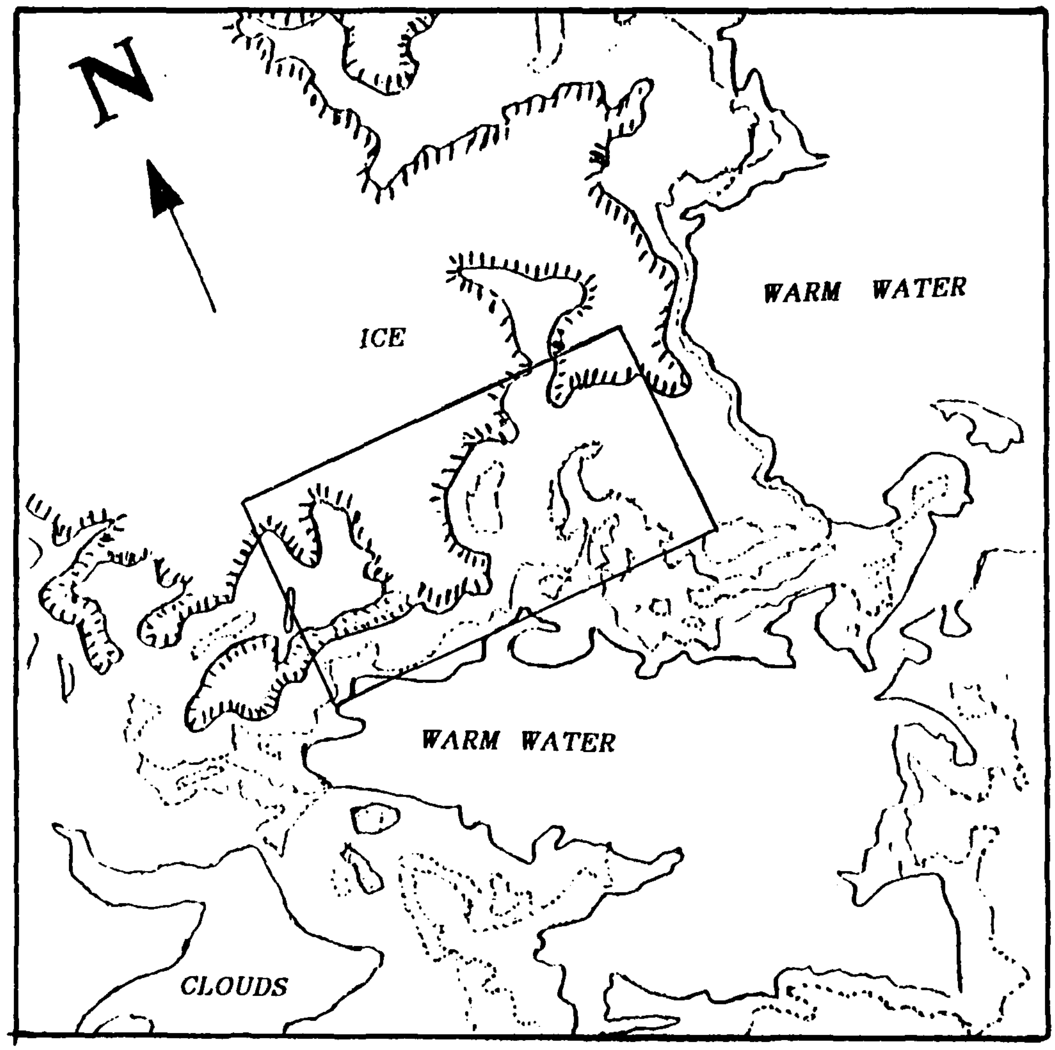


Figure 16. Enlargement of Figure 15 to isolate the operational area (indicated by the box) of the experiment.

photos alone. However, a fairly accurate estimate was made by relating known geographic features from a map to those on the small scale photographs and estimating the coordinates of the ice edge. The 90 GHz imager pictures were helpful also since the start and finish latitude and longitude of each leg were known. Figure 17 shows a black and white version of the original color print provided by NRL reduced in size. The latitude and longitude are approximations since the six legs were not flown at exactly the same height and orientation and thus are also at slightly different scales.

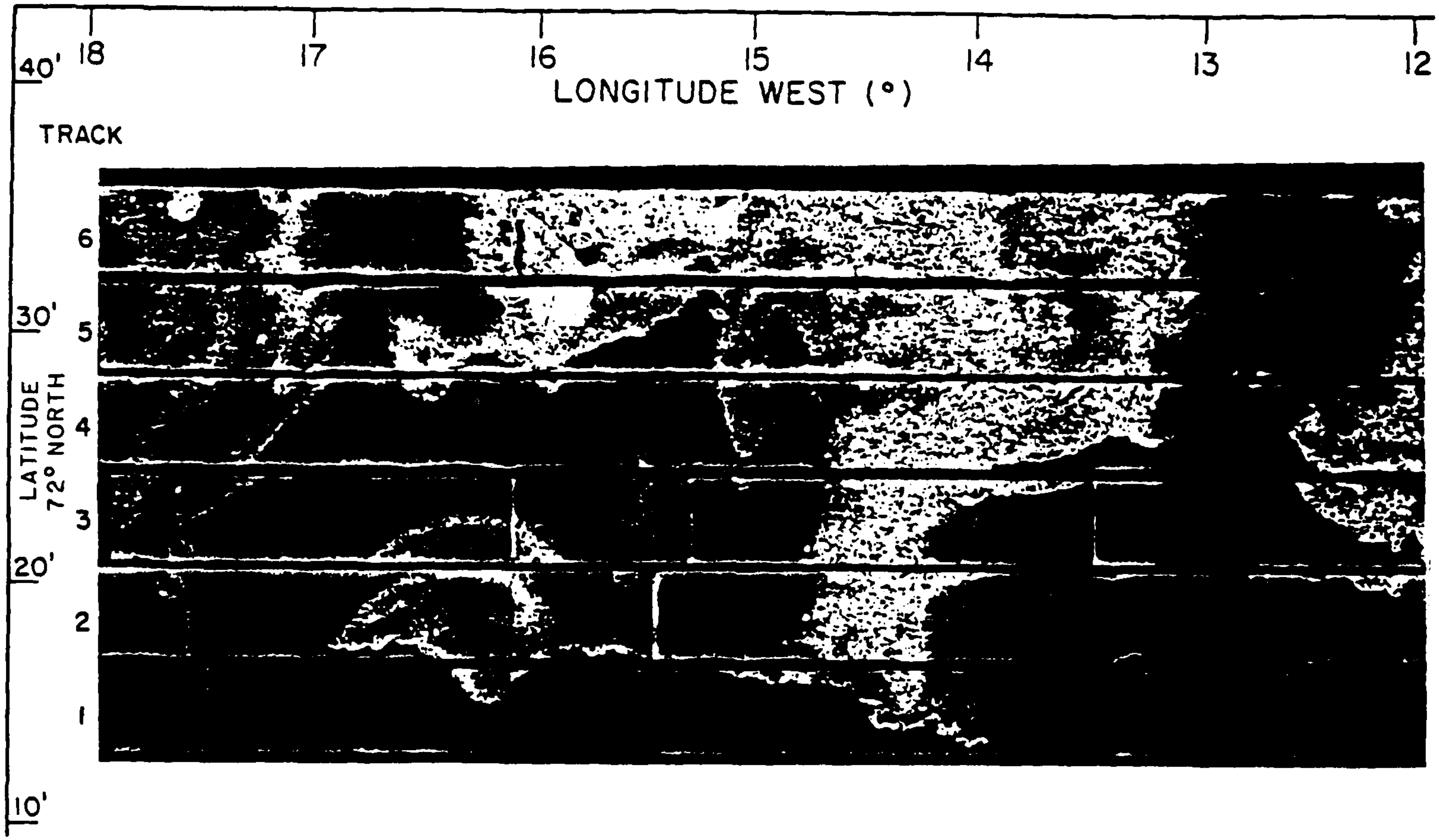


Figure 17. NRL Code 8311 90 GHz microwave radiometer imagery data from the high altitude ice edge overflights of 25 July 1987. Latitude and longitude are approximate. This is a copy of the color version.

IV. RESULTS

A. AMBIENT NOISE DATA

1. 27 July 1987

Of the eight channels used for ambient noise data collection, only four could be analyzed since the hard copy gram (each gram has four channels recorded on it) for the other four channels was not retained after the experiment. The four channels which did have a corresponding gram contained ambient noise data for five buoys. All buoys are referred to by their transmission channel number. Table III summarizes

Table III. MEDIAN AMBIENT NOISE LEVELS 27 JULY 87

Frequency	Buoy 4	Buoy 6	Buoy 12	Buoy 16	Buoy 23
30 Hz	78	76	71	73	70
40 Hz	80	79	73	79	72
50 Hz	82	79	74	79	71
100 Hz	81	79	76	80	73
200 Hz	79	76	76	77	73
315 Hz	78	74	72	74	70
400 Hz	74	72	70	72	68
500 Hz	73	70	69	70	66
600 Hz	71	67	67	69	63
700 Hz	69	66	67	67	62
800 Hz	68	64	63	66	61
900 Hz	67	62	63	66	60
1000 Hz	68	63	62	66	59
1100 Hz	66	61	61	65	58
1200 Hz	65	60	60	64	56

(Note: ambient noise levels are in dB re $1uPa^2/Hz$)

the median ambient noise levels recorded on 27 July for buoys 4, 6, 12, 16 and 23. Buoys 4 and 6 were set deep (1000 ft) while 12, 16 and 23 were set shallow (60 ft). The number of samples (minutes) of analyzed data used to determine the median noise level was as follows: 17 for buoy 4; 14 for buoy 6; 15 for buoy 12; 11 for buoy 16; and 32 for buoy 23. The spread in the median ambient noise levels of Table III, determined from the 10th and 90th percentiles, is shown in Table IV. It is apparent that there is temporal variability in the ambient noise levels over the relatively short observation period.

Figure 18 illustrates how the spectral amplitudes of each of these buoys compare. The frequency range extends only

Table IV. SPREAD IN AMBIENT NOISE LEVELS 27 JULY 87

Frequency	Buoy 4	Buoy 6	Buoy 12	Buoy 16	Buoy 23
30 Hz	3.7	4.0	2.8	2.8	5.3
40 Hz	2.6	2.9	7.9	4.5	7.1
50 Hz	3.3	3.1	7.4	3.5	5.7
100 Hz	2.1	2.5	2.5	1.9	1.5
200 Hz	1.3	1.4	3.0	2.7	2.2
315 Hz	2.1	1.4	4.0	3.1	3.7
400 Hz	3.0	2.3	2.7	3.8	2.7
500 Hz	3.1	6.0	2.9	4.6	2.5
600 Hz	2.8	1.6	3.0	3.1	2.1
700 Hz	4.3	1.8	2.6	3.7	2.1
800 Hz	3.6	2.1	3.0	2.3	1.8
900 Hz	6.8	1.6	7.8	2.6	2.6
1000 Hz	9.5	0.9	1.0	5.8	2.8
1100 Hz	7.0	1.5	1.8	1.4	2.4
1200 Hz	4.9	1.6	1.4	2.1	2.4

(Note: spread in ambient noise levels is in dB re $1 uPa^2/Hz$)

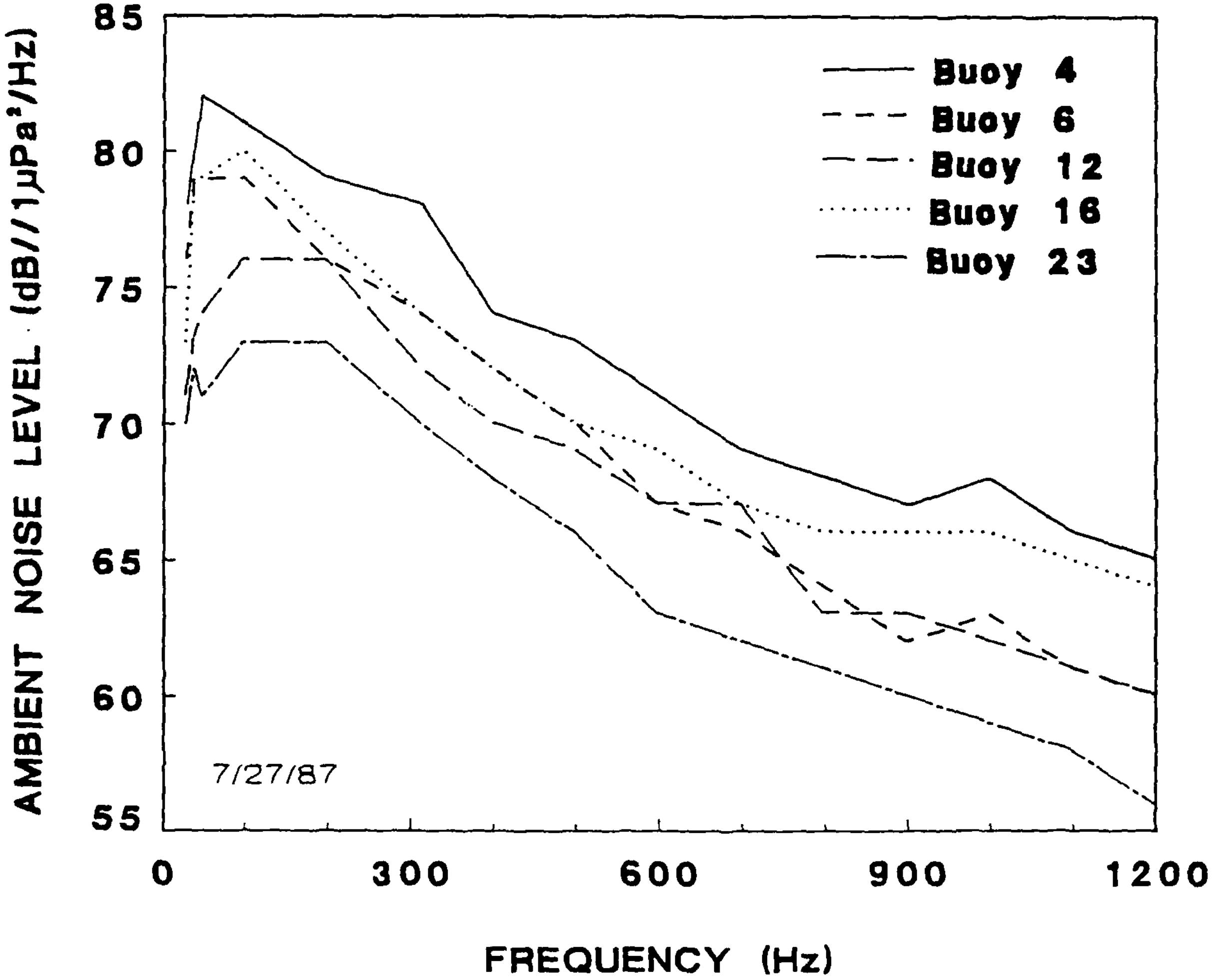


Figure 18. Comparison of ambient noise levels (power spectra) from 0-1200 Hz for buoys deployed on 27 July 1987. Buoys 4 and 6 were set deep (300 ft or 91 m). Buoys 12, 16, and 23 were set shallow (60 ft or 18 m).

to 1200 Hz due to the smaller bandwidth of the recording as discussed earlier. Appendix B contains a separate plot of the median noise spectrum levels for each buoy and the associated 10th and 90th percentile values. Included in Appendix B are separate plots of the mean ambient noise levels. From Figure 7, the loudest buoys (4 and 16) were located at the ice edge and close to the hot spot as determined by triangulation from the research vessel. Buoy 6, also exibiting significant noise levels, was near the previous day's hot spot and surrounded on three sides by ice at a distance of about 8 km. Buoy 23, the quietest buoy, was approximately 2 km south of the ice edge. Buoy 12, on the other hand, had levels in between those of 16 and 23 and was located just inside the ice edge to the east which forms a sort of penninsula feature.

2. 28 July 1987

The 14-track tape copy analyzed for this thesis included only four of the original eight ambient noise data channels. The second copy of this day's tape which arrived on 15 November 1988 contained all eight sonobuoy channels as well as a usable time code, but was too late to be of use as stated before. For the 35 minute interval of the tape studied, each of the four channels contained ambient noise data for a separate buoy. The buoys analyzed were 18, 20, 28, and 29. These buoys account for two of the four pairs that were deployed. The first pair was comprised of 18 (shallow, 60 ft) and 28 (deep, 300 ft) which were directly on top of the hot spot about 8 km west of the ice edge. The second pair, 20 (shallow) and 29 (deep), were placed to the northwest of the first pair and approximately 8 km from the ice edge.

Two analyses were done on this data as noted previously: one with an effective resolution bandwidth of 1.5 Hz and one with 7.5 Hz. The 7.5 Hz resolution bandwidth, corresponding to a frequency span of 0-2000 Hz, was the basis for Setup 1 as depicted earlier in Table I. The 1.5 Hz high resolution bandwidth, corresponding to a frequency range of 0-400 Hz, was the basis for Setup 2. To distinguish between the different bandwidths for the same buoy in the discussion and tables which ensue, a buoy number followed by (A) indicates Setup 1 and when followed by (C) indicates Setup 2. Table V summarizes the median ambient noise levels for both setups. Figure 19 shows graphically how the median ambient noise levels of all the buoys determined by using Setup 1 compare. The median ambient noise levels resulting from use of Setup 2 are shown in Figure 20a. To illustrate how the results from the two different setups compare, the results from Setup 1 in the range 0 to 400 Hz are shown as Figure 20b on the same page. It is readily apparent that they compare very favorably. The spread of each of the ambient noise levels listed in the previous table are given in Table VI. The temporal variability of the ambient noise levels noted earlier for 27 July is evident on this day as well but to a slightly higher magnitude.

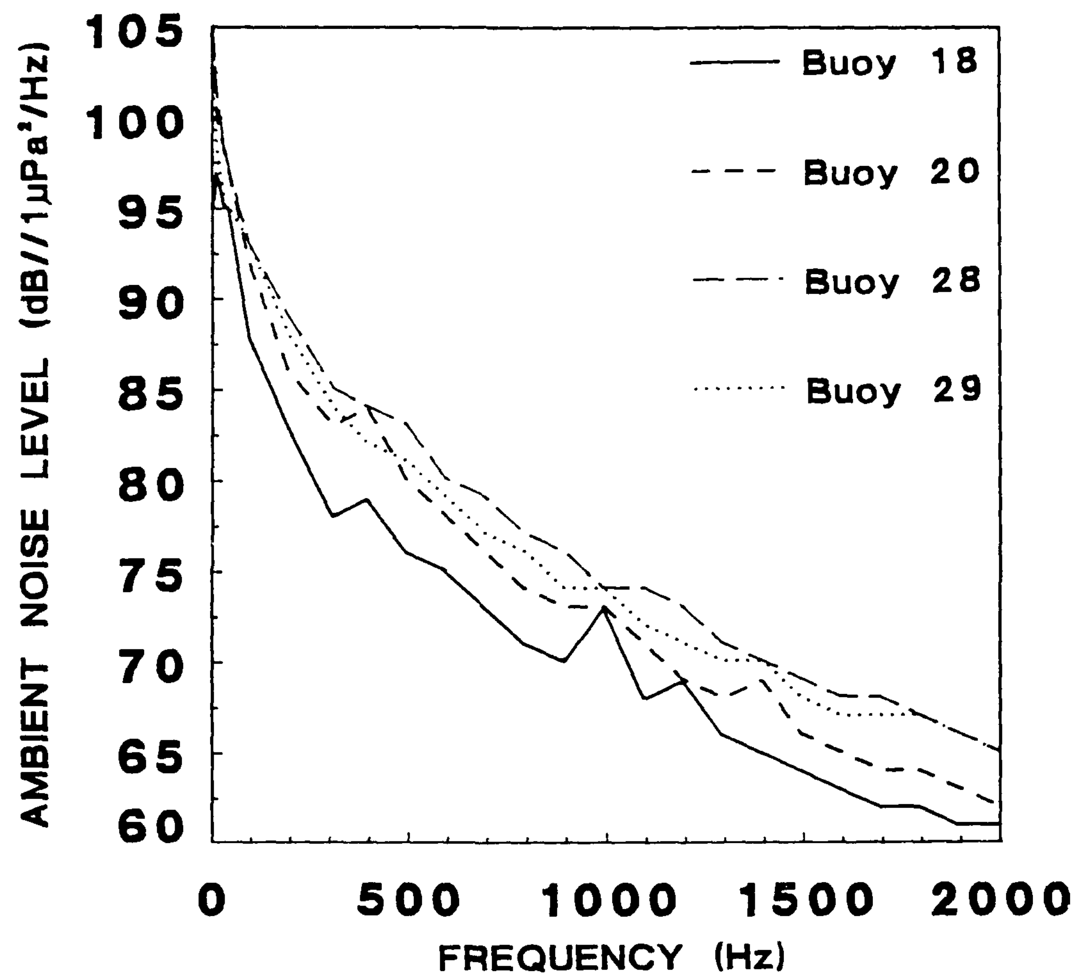
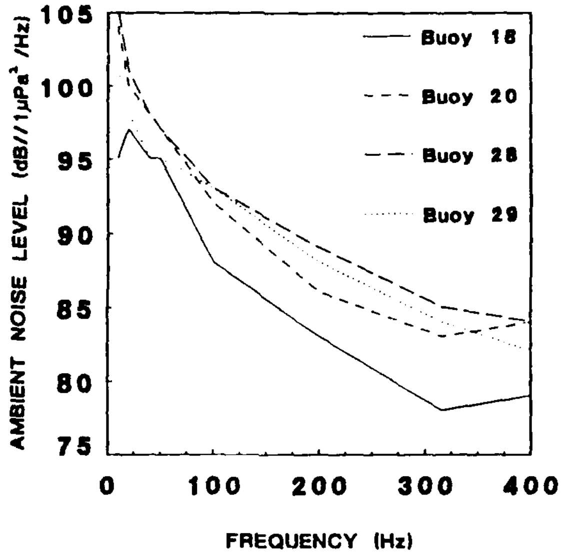


Figure 19. Comparison of ambient noise levels (power spectra) from 0-2000 Hz for buoys deployed on 28 July 1987. Buoys 28 and 29 were set deep (1000 ft or 305 m). Buoys 18 and 20 were set shallow (60 ft or 18 m).

(a)



(b)

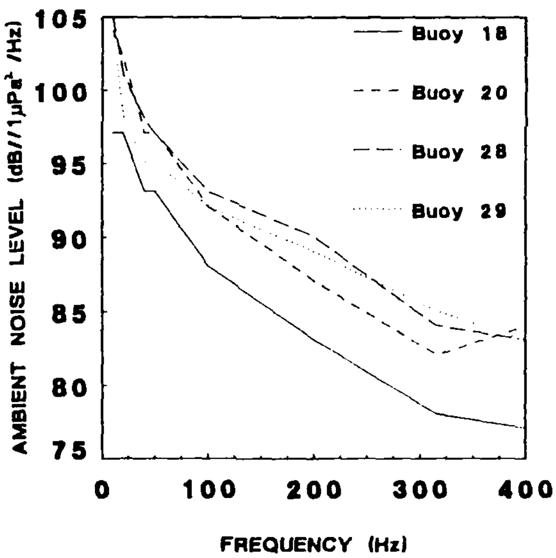


Figure 20. Comparison of ambient noise levels (power spectra) from 0-400 Hz for buoys deployed on 28 July 1987 obtained with different resolution bandwidths. (a) Setup 1 with an effective resolution of 7.5 Hz. (b) Setup 2 with an effective resolution of 1.5 Hz.

Table V. MEDIAN AMBIENT NOISE LEVELS 28 JULY 87

Frequency	Buoy 18		Buoy 20		Buoy 28		Buoy 29	
	(A)	(C)	(A)	(C)	(A)	(C)	(A)	(C)
10 Hz	95	97	104	104	105	105	101	104
20 Hz	97	97	100	102	101	101	98	98
40 Hz	95	93	98	97	98	98	95	95
50 Hz	95	93	97	97	97	97	95	95
100 Hz	88	88	93	92	93	93	93	92
200 Hz	83	83	89	87	89	90	88	89
315 Hz	78	78	85	82	85	84	84	85
400 Hz	79	77	84	84	84	83	82	83
500 Hz	76		80		83		81	
600 Hz	75		78		80		79	
700 Hz	73		76		79		77	
800 Hz	71		74		77		76	
900 Hz	70		73		76		74	
1000 Hz	73		73		74		74	
1100 Hz	68		71		74		72	
1200 Hz	69		69		73		71	
1300 Hz	66		68		71		70	
1400 Hz	65		69		70		70	
1500 Hz	64		66		69		68	
1600 Hz	63		65		68		67	
1700 Hz	62		64		68		67	
1800 Hz	62		64		67		67	
1900 Hz	61		63		66		66	
2000 Hz	61		62		65		65	

Note: Ambient noise levels are in dB re 1uPa^2/Hz
(A): Setup 1 [0-2 kHz] (C): Setup 2 [0-400 Hz]

Table VI. SPREAD IN AMBIENT NOISE LEVELS 28 JULY 87

Frequency	Bouy 18		Bouy 20		Bouy 28		Bouy 29	
10 Hz	9.8	6.5	12.6	11.1	4.7	4.9	12.3	31.0
20 Hz	6.0	6.8	5.7	5.0	3.5	2.8	9.0	8.8
40 Hz	6.5	7.0	3.2	4.0	2.0	2.6	5.1	5.0
50 Hz	6.4	7.8	3.1	3.6	1.7	2.1	3.8	4.5
100 Hz	7.2	8.1	1.8	2.2	1.3	1.4	2.5	2.5
200 Hz	9.0	7.9	5.2	7.4	4.5	2.1	3.4	6.7
315 Hz	8.3	8.7	2.7	3.1	2.1	2.5	2.1	3.5
400 Hz	10.1	11.1	4.3	4.7	5.6	2.0	2.0	1.6
500 Hz	8.4		3.2		2.3		2.5	
600 Hz	7.3		3.2		1.5		1.2	
700 Hz	8.0		3.3		4.2		2.4	
800 Hz	7.6		4.6		1.8		1.4	
900 Hz	8.5		3.8		2.0		2.4	
1000 Hz	7.9		2.8		1.8		2.1	
1100 Hz	8.1		1.8		2.2		1.3	
1200 Hz	7.4		2.7		2.9		2.5	
1300 Hz	7.9		3.2		2.2		3.1	
1400 Hz	8.0		3.7		2.7		5.8	
1500 Hz	7.7		2.6		3.0		2.5	
1600 Hz	7.6		2.3		2.1		2.3	
1700 Hz	8.8		1.8		2.1		3.2	
1800 Hz	8.2		2.7		1.8		2.4	
1900 Hz	8.1		1.8		2.1		4.2	
2000 Hz	8.5		1.4		2.1		4.2	

(Note: spread in ambient noise levels is in dB re $1 uPa^2/Hz$)

B. OCEANOGRAPHIC/ENVIRONMENTAL DATA

Figure 21 shows the detailed bathymetry of the study region from 70°N-74°N, 0°W-25°W. In this figure, a significant easterly excursion of the 2000 m isobath, and thus the continental slope, occurs at about 72°30'N, 15°30'W associated with a long and narrow ridge which rises to a depth shallower than 1000 m. This significant bathymetric change diverts the EGC causing a portion of it to be shunted eastward and form the Jan Mayen Polar Current (JMPC) as shown earlier in Figure 1. A more detailed view of this ridge is shown in Figure 22 from which much of it is observed to lie within the operational area (indicated by the grid) of the experiment. There is a strong suggestion that bathymetric steering of the EGC and ice edge occurs because of the presence of the ridge.

The area under investigation lies at the southeastern corner of the local marginal ice zone as shown in Figure 23. In this figure, which is derived from Figure 15, the shaded regions indicate depths shallower than 1000 m and are estimates of the locations of the two ridges identified in the previous figure. The circled numbers represent two outflow regions of polar water. The first is believed to be due to that part of the EGC diverted eastward by the topographic high described above and also that part steered eastward by the smaller ridge (71°54'N, 13°45'W). The main contributor to this outflow appears to be the smaller ridge. The flow is initially eastward north of the main ridge and then southeastward as it

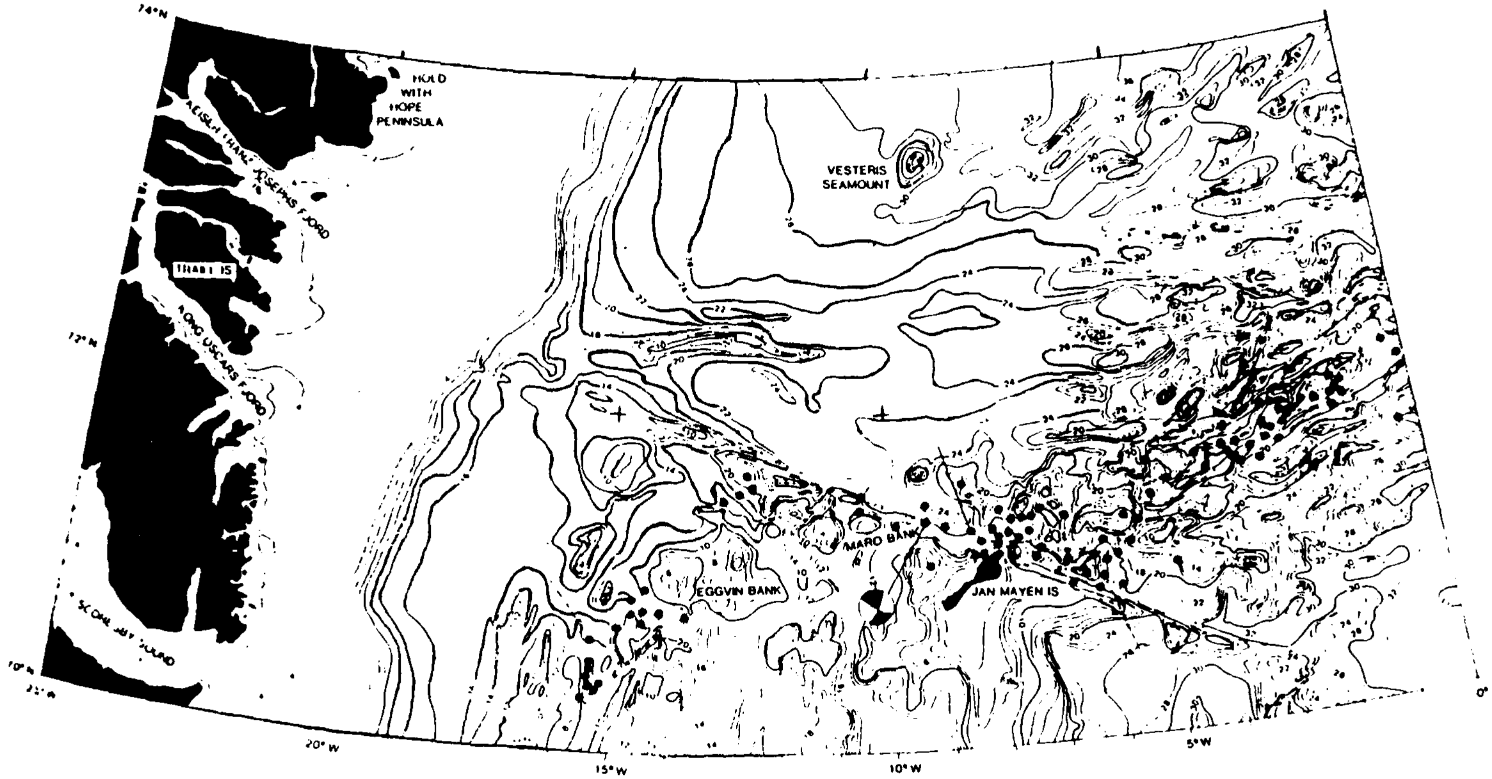


Figure 21. Bathymetry (in hundreds of meters) near the western end of the Jan Mayen Fracture Zone [from *Perry et al.*, 1980].

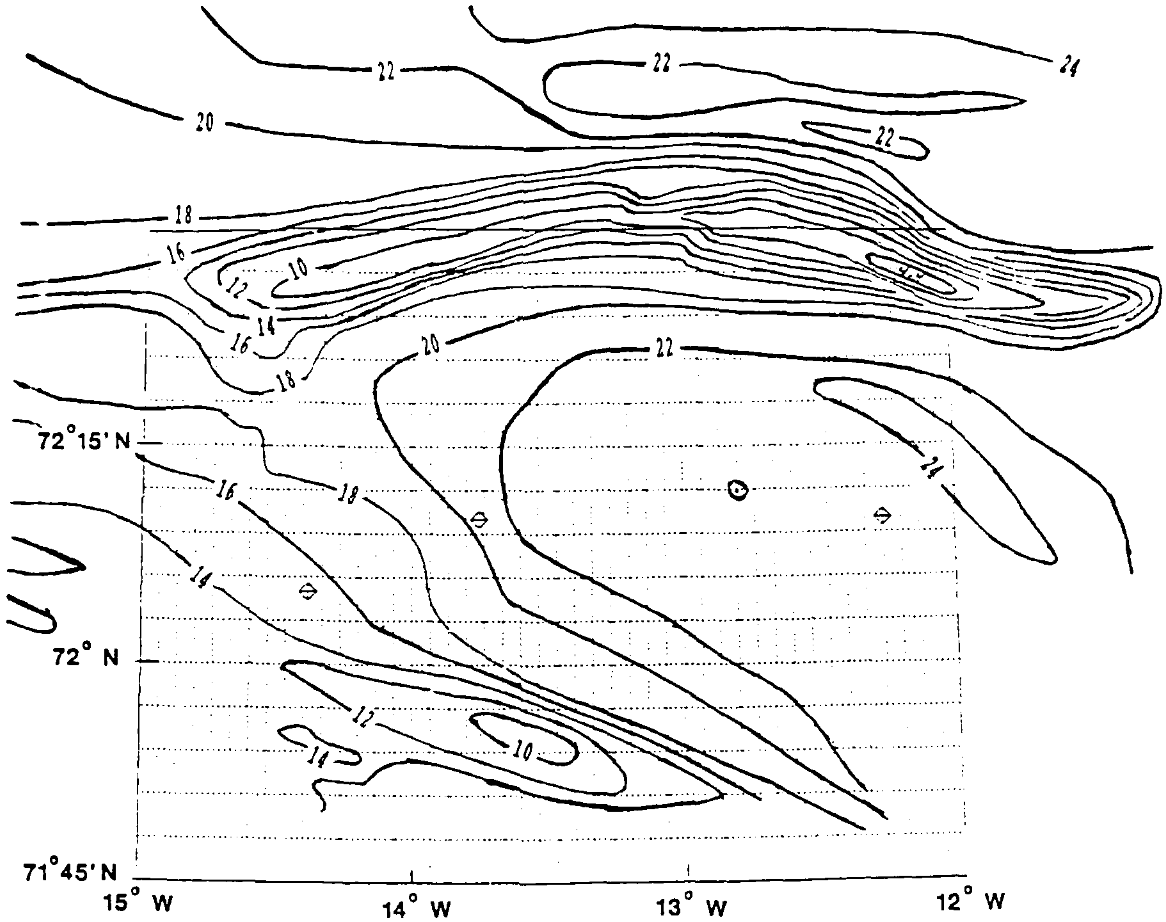


Figure 22. Detailed bathymetry (in hundreds of meters) derived from Figure 21 near the study area showing hot spot locations. Very distinct are the two ridges (a large one to the north and a smaller one to the south) and the topographic low between them. This is the source for the bathymetry shown in the other figures.

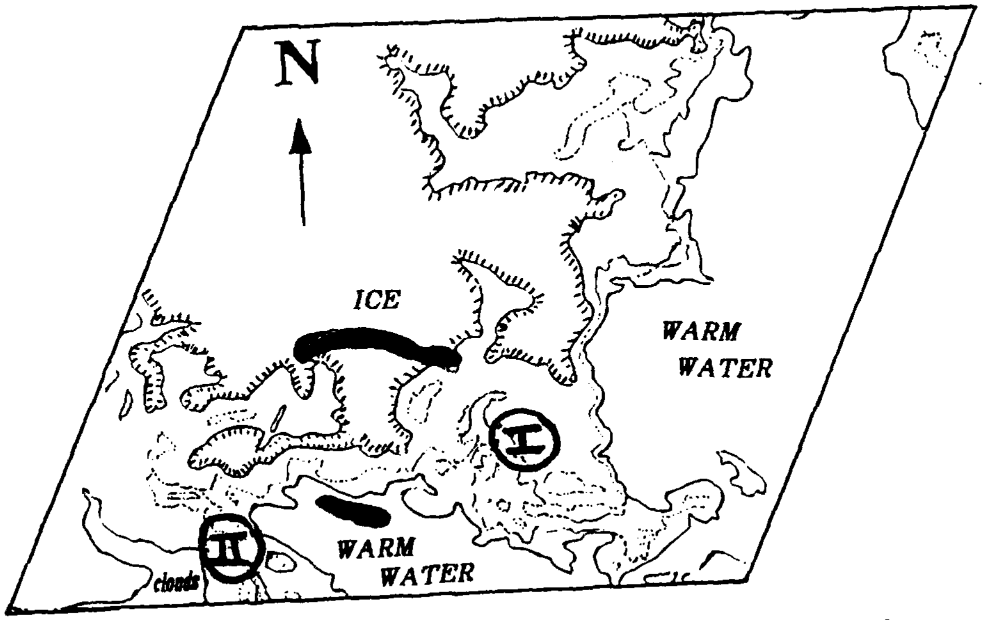


Figure 23. Southeastern corner of the MIZ on 25 July 1987 where protruding ice tongues illustrate two regions of cold water outflow. Region I is a result of flow from the region between the two ridges and the flow north of the large ridge which leads to the JMPC. Region II is due to flow south of the smaller ridge. The blackened areas indicate bathymetric depths less than 1200 m.

passes over the ridge and comes under the influence of the smaller ridge. The second region is possibly due to the south-eastwardly flow south of the smaller ridge and the Maro Bank region of the Jan Mayen Fracture Zone. This flow does not contribute to the JMPC. The patch of warm water in the lower right of the figure appears to lie over the Maro Bank region. The proposed flow pattern in the first region suggests a cyclonic circulation pattern. Figure 24 summarizes the hypothesised flow pattern. No current measurements were made to verify this flow but, the 5, 10, and 18 m temperature contour plots (Figures 10-12) support this hypothesis.

The lack of geographical coordinates on the satellite photos complicates the analysis. In addition, the sea-ice boundary shows up very faintly, if at all, on the satellite pictures due to the resolution at which they were processed. From the four day sequence of satellite photos, the ice pack and MIZ, already quite diffuse, appear to have become more diffuse in the north-south direction as they moved slowly south with the currents but slightly more compact in the east-west direction. This is probably a result of the winds which blew from out of the W-SW and ranged in speed from 3 to 20 kts during the period 24-27 July before subsiding on 28 July to maximum of 4 kts. The maximum sea state went from 4 on 25 July to 1 on 28 July.

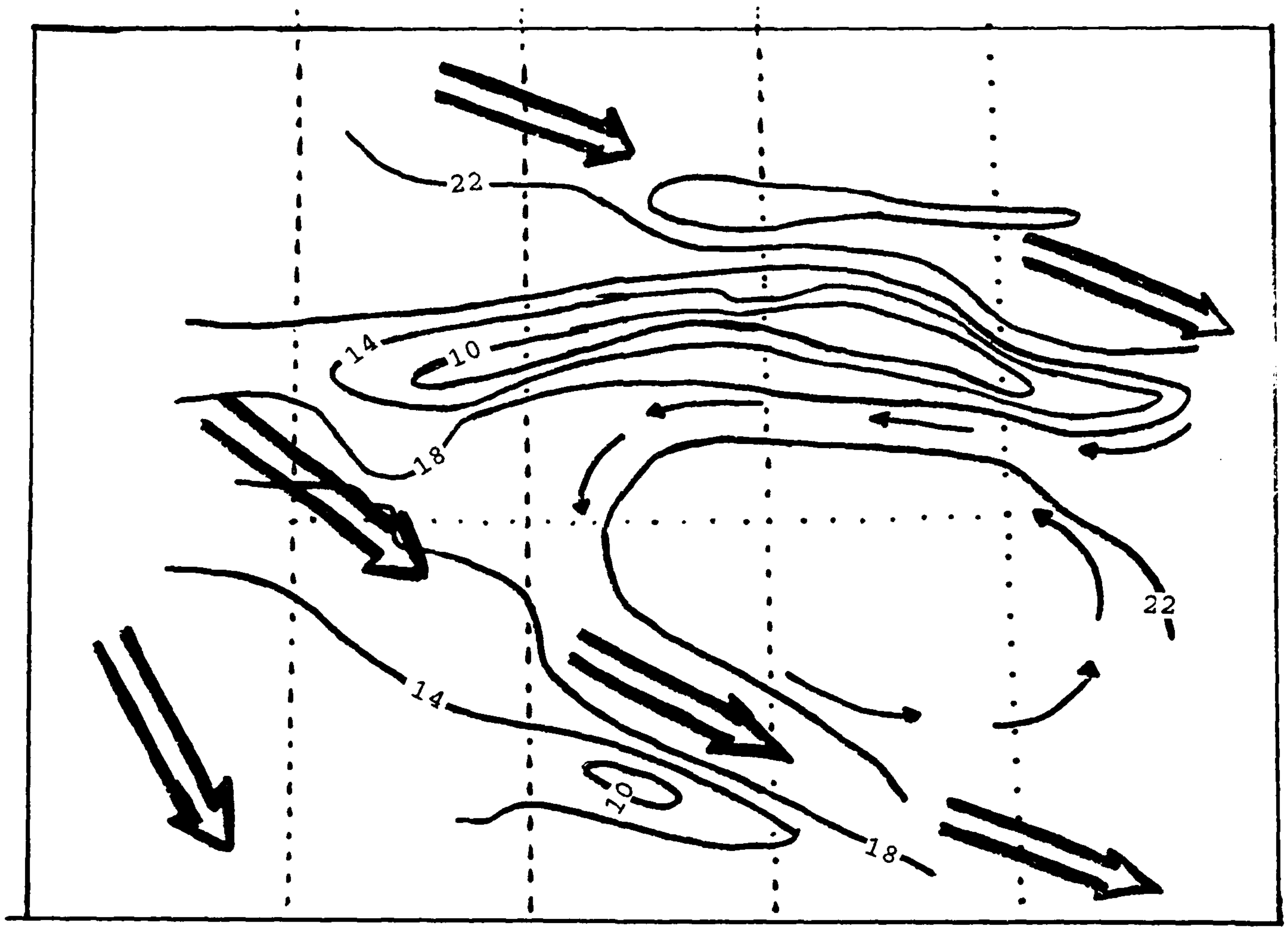


Figure 24. The hypothesized flow pattern over the bathymetry (in hundreds of meters) in the study area. The area of cyclonic circulation is of particular importance since it supports the possibility of an eddy existing in the area.

VI. DISCUSSION OF RESULTS

A. THE PRESENCE OF AN MIZ EDDY

Although the remote sensing information does not explicitly reveal the presence of an eddy, it does not discount its possibility either. The temperature contour plots (Figures 10-12) in conjunction with the detailed bathymetry seem to reveal the presence of a large, topographically triggered mesoscale eddy centered at about 72°11'N, 012°50'W which is in the middle of the cyclonic circulation indicated earlier in Figure 24. It is estimated to be elliptical in shape, with major and minor axes of 50 and 30 km respectively, and cyclonic in circulation. It is oriented with its major axis running northwest to southeast. The position of the center of this proposed eddy with respect to the bathymetry, hot spots, and ice edge is shown in Figure 25 as located above a topographic depression (with a depth greater than 2200 m) that lies between the two ridges. That portion of the ice edge observed over the four day period of this experiment is thought to have moved through the eddy from west to east while being steadily influenced by west-southwest winds.

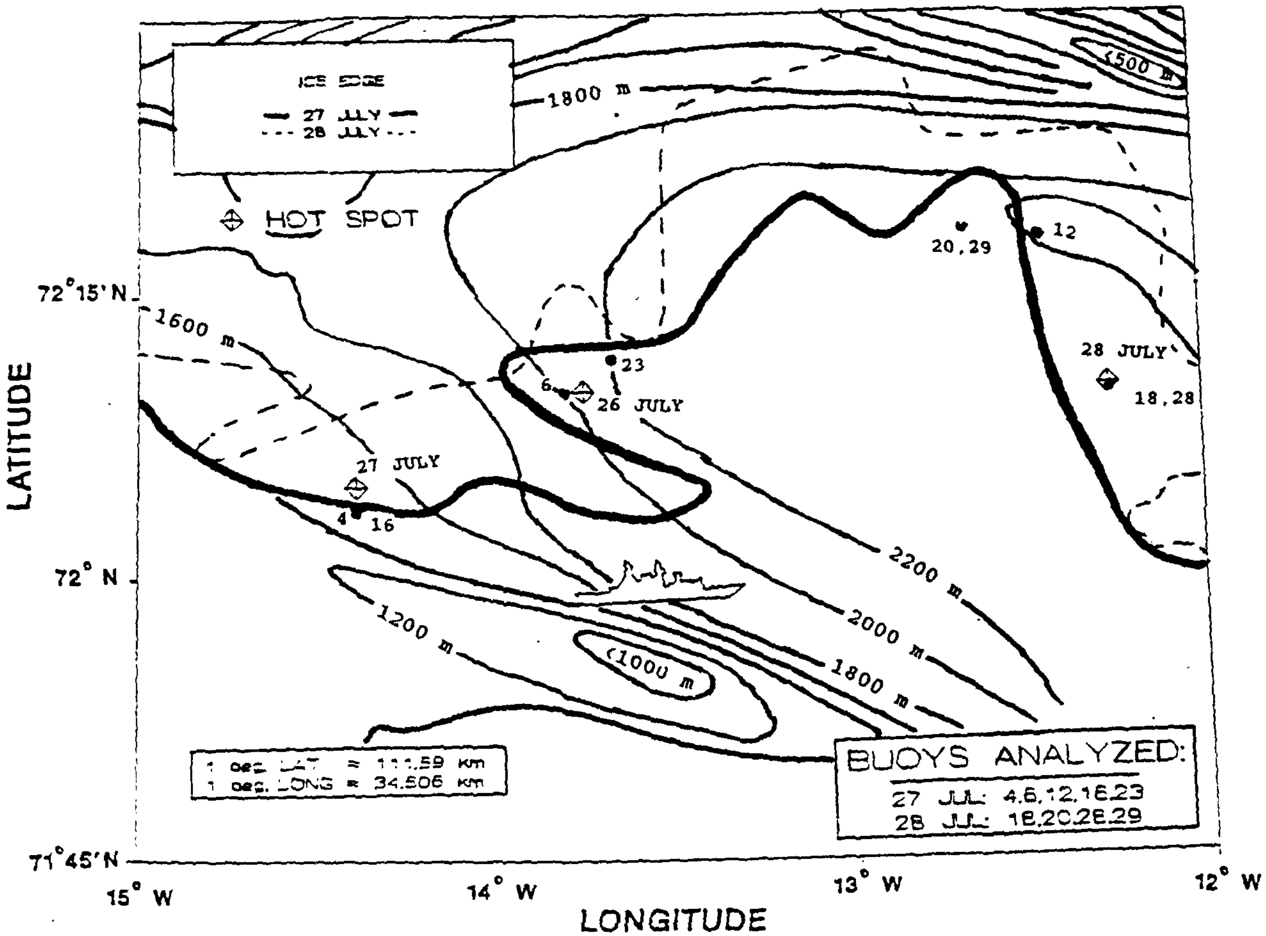


Figure 25. A composite plot showing the agreement between bathymetry (in meters) and the radar ice edges of 27 and 28 July 1987. Ambient noise buoy and hot spot locations are also indicated.

B. 27 JULY 1987

This day's hot spot was located in a region of ice divergence (near the beginning of cold water tongue, see e.g. Figure 10). This divergence is probably due to a combination of the presence of the eddy and the diversion of some of the EGC flow which aided the formation of the eddy. The proposed eddy location is east of this hot spot position. The small ice tongue apparent in Figure 7 is indicative of divergence and most likely the result of entrainment of the ice by the cyclonic circulation of the eddy. On-ice winds, averaging 9 kts from 275°T, appear to produce an area of local convergence on the west side of the ice edge next to this hot spot. As can be seen from Figure 10, the strongest temperature gradients are to the immediate west and south of the hot spot. Thus the ambient noise levels observed are believed to be due to the combination of the breaking of ice associated with divergence and the ice collisions due to wind-induced convergence, with divergence being the dominant factor. Swell data would be helpful in this analysis of generating mechanisms but was not recorded during the experiment.

Taking a look at the individual ambient noise levels, buoy 4, located at the hot spot at a depth of 1000 ft (305 m), had the highest amplitdes at all frequencies. Buoy 16, also at the hot spot but at a depth of 60 ft (18 m), was the second loudest at almost all frequencies. Because of the configuration of the ice and the assumed water flow, it is not surprising that the noise amplitudes of these two buoys were louder than the other three. This lends creedance to the evaluation of the location as a hot spot. It is interesting, however, that the deep buoy was louder (1-3 dB) than the shallow one. This result is true for the other buoy pair (6 deep and 23 shallow) as well. This latter buoy pair was separated by about 3 km and thus the two buoys were not as close together as the other pair. Buoy 23, with the lowest levels of all buoys on this day, was closer to the ice edge than buoy 6. The one remaining buoy, number 12, was located just inside (2 km) the ice edge almost 50 km northeast of buoys 6 and 23. Its levels were in between those of the other two shallow buoys. The observed levels were of the same magnitude as those of *Johannessen et al.* [1988] for 19 June 84.

C. 28 JULY 1987

The hot spot identified on this day was approximately 2 degrees of longitude (70 km) to the east of the 27 July hot spot. It is believed to be in a region of eddy convergence as shown in Figure 25. Also, from Figure 7, the large penninsula feature developed curvature on its west side as it moved to the east which supports the presence of the proposed eddy. This day was quieter than the previous day with respect to sea state and winds. However, the ambient noise levels were still very high for all frequencies. This same interesting result was found by *Johannessen et al.* [1988] for 30 April 85. In the absense of strong winds or high sea state, the ice interactions are predominately caused by horizontal shear velocity arising from the current and eddy circulation [*Johannessen et al.*, 1988]. The slight winds present were on-ice at the ice edge closest to the hot spot. This suggests that ambient noise levels in regions of eddy convergence may be of higher amplitudes than those in the regions of divergence due to the larger area and higher ice concentration of the covergence region.

For buoy pair 18 (60 ft or 18 m) and 28 (300 ft or 91 m) positioned at the hot spot, the deep buoy is again louder at all frequencies. This holds true for the second pair as well. Buoy 20 (300 ft) is slightly louder than buoy 29 (60 ft) at all frequencies except 400 Hz where a signal of unknown origin is believed to have affected the data. The shallow buoys were expected to be louder than the deep buoys since they were located in the surface sound channel where the ice interactions were occuring. Distant heavy shipping may account for the fact that the deep buoys were louder but this is not known to actually be the case. There was no indication of the bouys malfunctioning.

VII. CONCLUSIONS AND RECOMMENDATIONS

In July 1987, NRL conducted an acoustic experiment in the Greenland Sea marginal ice zone (MIZ). Several ambient noise hot spots or concentrated areas of relatively high noise levels were found at the ice edge using a towed array. Ambient noise levels were obtained on 27 and 28 July with AN/SSQ-57A and AN/SSQ-57XN5 calibrated sonobuoys. The temperature structure of the area was determined using XBT (ship) and AXBT (P3C aircraft) buoys placed inside and outside the ice edge. The ice edge was determined from coincident satellite photos, 90 GHz microwave imager data, and P3C radar ice edge maps. Wind speed and direction and sea state were recorded on the ship.

The study area was sampled well enough to indicate that a variable ambient noise field of significantly high levels existed in the region of the hot spots. In addition, the temperature contour data, bathymetry, and ice edge features and locations seemed to reveal the presence of a large mesoscale eddy embedded in the ice edge which is topographically controlled. There appears to be a definite relationship between the observed hot spots and the presence of this eddy. The 27 July hot spot is believed to be associated with a predominately divergent region (there was some local wind-induced convergence) while the 28 July hot spot is probably associated with a region of convergence. The ambient noise levels on 28 July, the quietest day with respect to sea state and wind speed, were higher than those of 27 July suggesting that eddy convergence regions are louder than eddy divergence regions due to the larger area and higher ice concentrations found in the former region. In the absense of high winds or sea state, the ice interactions are predominately caused by horizontal shear velocities arising from the current and eddy circulation. For every pair of colocated buoys analyzed, the deep buoy had slightly higher amplitudes. This was the opposite of what was expected. No explanation other than the possibility of distant shipping can be given to support this result. A larger number of buoys analyzed over much longer periods of time are needed to investigate this occurance.

There are a number of recommendations, based on the analysis of this experiment, that should prove valuable to the follow-on experiment scheduled for next year. More oceanographic/environmental data should be taken such as CTD, current measurements, swell height and direction, detailed visual observations of the weather and ice, air temperature and barometric pressure. The bathymetry of the operation area should be a prime consideration in the placement of sonobuoys and XBT's since the visual observations will not always give accurate locations of the fronts and eddies. It would also be helpful to place a buoy in a known "quiet spot" for comparison purposes.

The procedures for collection of ambient noise data onboard the aircraft should be standardized for the experiment to facilitate analysis of the data. In particular, calibration tones of known amplitudes should be recorded on each channel of the tape. The flight grams need to be annotated to the highest degree of detail possible. A separate log (possibly just a pocket tape recorder) detailing buoy information, channel changes, etc. should be maintained. Most importantly, all of the data collected needs to be accounted for after the flight (correct number of tapes, etc.).

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APPENDIX A

QUICKBASIC 4.0 COMPUTER-CONTROL PROGRAM

```
'PROGRAM: SD375.BAS
'DATE:    10/19/88
'AUTHOR:  LT KRIS BIGGS, USN
'PURPOSE: CONTROL SD375 DATA ACQUISITION AND FILE CONVERSION USING
'         NATIONAL INSTRUMENTS GP-IB INTERFACE CARD (IEEE-488) AND NEC
'         APC IV PERSONAL COMPUTER (IBM/AT COMPATIBLE).
COMMON SHARED IBSTA%, IBERR%, IBCNT%
DECLARE SUB InitialSetup ()
DECLARE SUB GetPrecisionData ()
DECLARE SUB PrintFiles ()
DECLARE SUB AskIfPrintoutWanted ()
DECLARE SUB CheckStatus ()
DECLARE SUB ResetClock ()
DECLARE SUB ConvertRawData ()
DECLARE FUNCTION MakeReal! (B1%, B2%, B4%)
DEFINT A-Z  'all untyped var are integers
OPTION BASE 1
TYPE RecordType1
  DataDate AS STRING * 10        'date of data
  ChannelID AS STRING * 3        '1-A,2-B,etc..
  Time0 AS STRING * 8            'SAMPLE TIME
  Freq1 AS SINGLE                 '40 HZ
  Freq2 AS SINGLE                '100 HZ
  Freq3 AS SINGLE                '315 HZ
  Freq4 AS SINGLE               '1000 HZ
  Freq5 AS SINGLE               '1500 HZ
END TYPE
TYPE RecordType2
  Freq AS INTEGER       'center freq of bin
  Voltage AS SINGLE     'magnitude of voltage in bin
  Level AS SINGLE       'magnitude in dB
END TYPE
DIM ChA AS RecordType1
DIM ChB AS RecordType1
DIM Spectrum AS RecordType2
DIM PrecisonData AS STRING * 6402
DIM RawData AS STRING * 3200
DIM Averaging%(1 TO 2)
DIM Volt(1 TO 400)
DIM Level(1 TO 400)
CLS : SCREEN 0, 1: COLOR 14, 0: WIDTH 80, 25
'this converts the precision data file created by a previous run PRINT
"Do you want to do file conversion now [Y/N]?": A$ = INPUT$(1)
```

```
IF UCASE$(A$) = "Y" THEN
 CALL ConvertRawData
 CLS
END IF
'Data collection?
PRINT "Do you want to collect data now (Y/N)?": A$ = INPUT$(1)
IF UCASE$(A$) = "N" THEN GOTO EndProgram
File1$ = "ChanA":          File2$ = "ChanB"
CALL IBFIND("SD375", SD375%): CLS   'open device
CALL InitialSetup: CLS : COLOR 14, 0
PRINT TAB(19); "SD 375 is correctly configured and ready to begin.":
PRINT
PRINT TAB(19); "The front panel is not locked out.": PRINT
COLOR 9, 0: LOCATE 10, 20: PRINT "Do"; : COLOR 30, 0: PRINT " NOT ";
COLOR 9, 0: PRINT "change any of the front panel settings!"
COLOR 14, 0: LOCATE 18, 20
PRINT "Press [C] to continue or [A] to abort program": A$ = INPUT$(1)
WHILE NOT (UCASE$(A$) = "A" OR UCASE$(A$) = "C")
 LOCATE 18, 20
 PRINT "Press [C] to continue or [A] to abort program": A$ = INPUT$(1)
WEND
IF UCASE$(A$) = "A" THEN GOTO EndProgram ELSE CLS
LOCATE 15, 25: PRINT "Continuing...."
'open data files
OPEN "ChanA.DAT" FOR RANDOM AS #2 LEN = LEN(ChA)
OPEN "ChanB.DAT" FOR RANDOM AS #3 LEN = LEN(ChB)
OPEN "LPT1:" FOR OUTPUT AS #4                    'printer
OPEN "MagA.DAT" FOR APPEND AS #5 LEN = 3200      'raw data chA
OPEN "MagB.DAT" FOR APPEND AS #6 LEN = 3200      'raw data chB
RecordNumber2 = LOF(2) \ LEN(ChA)
RecordNumber3 = LOF(3) \ LEN(ChB)
CLS : COLOR 9, 0: LOCATE 3, 1
PRINT "ChanA.DAT will contain the data for channel A": PRINT
PRINT "ChanA.DAT currently contains "; NumberOfRecords2; " records."
COLOR 15, 0: LOCATE 7, 1
PRINT "ChanB.DAT will contain the data for channel B": PRINT
PRINT "ChanB.DAT currently contains "; NumberOfRecords3; " records."
LOCATE 11, 5: PRINT : COLOR 14, 0
PRINT "The existing records in these files will be retained. Even so,"
PRINT "These files should be backed up to a floppy disk."
PRINT : COLOR 25, 0: LOCATE 20, 18
PRINT "---> Press any key to continue <---": COLOR 14, 0
DO: LOOP UNTIL INKEY$ <> ""          'wait for user to press a key
DateToday$ = DATE$                   'saves actual date
'*****************************************************
DO
 CLS
 LOCATE 8, 15
 INPUT "Date of Data tape (mm-dd-yyyy)? ", DataDate$
 PRINT : PRINT "Start time of data sampling (hh:mm:ss)? "', StartTime$
 DO: LOCATE 12, 15: INPUT "The Hour is (00 - 24) "; Hour$
 LOOP UNTIL VAL(Hour$) >= 0 AND VAL(Hour$) <= 24
```

```
 PRINT
 DO: LOCATE 12, 15: INPUT "  and the minutes are (00 - 59)    ";Minutes$
  LOOP UNTIL VAL(Minutes$) >= 0 AND VAL(Minutes$) <= 59
 PRINT
 DO:LOCATE 12,15:INPUT"     and the seconds are (00 - 59)    "; Seconds$
 LOOP UNTIL VAL(Seconds$) >= 0 AND VAL(Seconds$) <= 59
 StartTime$ = Hour$ + ":" + Minutes$ + ":" + Seconds$
 LOCATE 12, 15: PRINT "The time entered is "; StartTime$; SPACE$(20)
 LOCATE 15, 15: PRINT "Are these correct (y/n)? ": A$ = INPUT$(1)
LOOP UNTIL UCASE$(A$) = "Y": CLS
DO
 LOCATE 10, 15
 INPUT "Enter the channel ID (i.e. 1-A) for CH A: ", ChA.ChannelID
 PRINT : LOCATE 12, 15
 INPUT "Enter the channel ID (i.e. 1-A) for CH B: ", ChB.ChannelID
 PRINT : LOCATE 15, 15
 PRINT "Are these correct (y/n)? ": A$ = INPUT$(1)
LOOP UNTIL UCASE$(A$) = "Y": CLS
ON TIMER(1) GOSUB DISPLAYTIME
TIMER ON
LOCATE 12, 20
'------------ sampling ------------------------------------------------
PRINT "Press [S] to start sampling, [E] to end.": A$ = INPUT$(1)
TIME$ = StartTime$
DO UNTIL UCASE$(A$) = "S" OR UCASE$(A$) = "E"
 LOCATE 14, 20: PRINT "Incorrect response. Please try again.": BEEP
 A$ = INPUT$(1)
LOOP: CLS
LOCATE 15, 30: PRINT "Conducting first sample": COLOR 1, 0
LOCATE 25, 50: PRINT "Press [F1] to quit sampling.": COLOR 14, 0
IF (UCASE$(A$) = "E") THEN GOTO EndProgram
Averaging%(1) = 1
ON KEY(1) GOSUB StopSampling
KEY(1) ON                                    '[F1] stops sampling
CALL IBSAD(SD375%, 115)
CALL IBWRT(SD375%, "MPB(A)/" + CHR$(13))     'MAKE PUSH BUTTONS ASCII
CALL IBSAD(SD375%, 111)                      'PUSH BUTTON GROUP 15
CALL IBWRT(SD375%, "39474846FF")             'M1, STOP, ERASE, START
TIME$ = StartTime$
Interval! = 59!
T1! = TIMER
DO: LOOP UNTIL TIMER - T1! > Interval!   'waits 59 sec to check status
DO WHILE Averaging%(1) = 1
 CALL CheckStatus
 LOCATE 1, 1: PRINT "Checking Status...Average in progress..."
LOOP                           'keeps checking status until not
averaging
LOCATE 1, 1: PRINT "Averaging complete"; SPACE$(50)
CALL GetPrecisionData                     'data for first sample
DO
 T1! = TIMER
 DO: LOOP UNTIL TIMER - T1! > Interval! - 1! 'waits 59 sec
```

```
 LOCATE 1, 1: PRINT "Averaging complete"; SPACE$(50)
 DO WHILE Averaging%(1) > 0
  CALL CheckStatus
  LOCATE 1, 1: PRINT "Average in progress..."
 LOOP               'keeps checking status until not averaging
 LOCATE 1, 1: PRINT SPACE$(70)
 CALL GetPrecisionData
LOOP                'loops until [F1] is pressed
StopSampling:
PrintOut:
 CALL ResetClock    'reset system clock
' CALL ConvertRawData
EndProgram:
' CALL AskIfPrintoutWanted
 CLS : PRINT "Program terminated."
END
'*****************************************************************
'***************** END OF PROGRAM ********************************
'*****************************************************************

DISPLAYTIME:
 LOCATE 2, 50: PRINT TIME$
 LOCATE 3, 50: PRINT SampleTime$; " = last sample"
RETURN

SUB InitialSetup                          'takes about 1 sec to execute
SHARED SD375%
CLS
PRINT TAB(30); "FREQUENCY SELECTION: ": PRINT
PRINT TAB(30); "   (1)   40 Hz": PRINT TAB(30); "   (2)  100 Hz"
PRINT TAB(30); "   (3)  315 Hz": PRINT TAB(30); "   (4) 1000 Hz"
PRINT TAB(30); "   (5) 1500 Hz": PRINT TAB(30); "   (6) All of them"
COLOR 9, 0
LOCATE 12, 26: PRINT "Enter desired frequency (1-6)"; : F% =
VAL(INPUT$(1))
WHILE F% < 1 OR F% > 6
  BEEP
  LOCATE 12, 26: PRINT "Enter desired frequency (1-6)"; : F% =
VAL(INPUT$(1))
WEND
SELECT CASE F%
  CASE F% = 1: RclPanel$ = "0F010DFF"    'PANEL 1     40
  CASE F% = 2: RclPanel$ = "0F020DFF"    'PANEL 2    100
  CASE F% = 3: RclPanel$ = "0F030DFF"    'PANEL 3    315
  CASE F% = 4: RclPanel$ = "0F040DFF"    'PANEL 4   1000
  CASE F% = 5: RclPanel$ = "0F050DFF"    'PANEL 5   1500
  CASE ELSE:   RclPanel$ = "0F060DFF"    'PANEL 6   All of them
END SELECT
COLOR 30, 0: LOCATE 16, 16                'Blinking yellow on black
PRINT "Performing initial setup."; : COLOR 14, 0
PRINT "This will take a few seconds."
CALL IBSAD(SD375%, 115)
```

```
CALL IBWRT(SD375%, "MPB(A)/" + CHR$(13))      'MAKE PUSH BUTTONS ASCII
CALL IBSAD(SD375%, 111)                       'PUSH BUTTON GROUP 15
CALL IBWRT(SD375%, RclPanel$)                 'PANEL #_ RCL
CALL IBWRT(SD375%, "1416010000000BFF")        'CH A 1000mv/EU
CALL IBWRT(SD375%, "1516010000000BFF")        'CH B 1000mv/EU
CALL IBWRT(SD375%, "1F1306000BFF")            'dB, AVG T = 60 SEC
CALL IBSAD(SD375%, 115)                       'GROUP 19 CONTROL
CALL IBWRT(SD375%, "MRI(A)/" + CHR$(13))      'MAKE RANGE INPUTS ASCII
CALL IBSAD(SD375%, 107)                       'GROUP 11 RANGE INPUTS
CALL IBWRT(SD375%, "330DFF")                  ' 0 - 2 volt, 0 - 2 Khz
'**************** ready to start data acquisition **********************

END SUB SUB GetPrecisionData STATIC
SHARED SD375%, PrecisionData AS STRING * 6402, DataDate$, T1!
SHARED ChA AS RecordType1, ChB AS RecordType1, SampleTime$
SHARED NumberOfRecords1, NumberOfRecords2, NumberOfRecords3
     Cell(1) = 16          '  40 Hz -----___
     Cell(2) = 40          ' 100 Hz -----___---
     Cell(3) = 126         ' 315 Hz -----___---===> CHANNEL A
     Cell(4) = 200         '1000 Hz -----___---
     Cell(5) = 300         '1500 Hz -----
     Cell(6) = 416         '  40 Hz -----___
     Cell(7) = 440         ' 100 Hz -----___---
     Cell(8) = 526         ' 315 Hz -----___---===> CHANNEL B
     Cell(9) = 600         '1000 Hz -----___---
     Cell(10) = 700        '1500 Hz -----
LOCATE 1, 1:   PRINT "Getting Precision data..."; SPACE$(45)
SampleTime$ = TIME$
TIMER OFF
CALL IBSAD(SD375%, 100)
CALL IBRD(SD375%, PrecisionData)     ' 3.2 sec
TIMER ON: T1! = 0
LOCATE 1, 1:   PRINT SPACE$(26); "...data received..."; SPACE$(15)
CALL IBSAD(SD375%, 115)                        'CONTROL GROUP
CALL IBWRT(SD375%, "MPB(A)/" + CHR$(13))       'MAKE PUSH BUTTONS ASCII
CALL IBSAD(SD375%, 111)                        'PUSH BUTTON GROUP 15
CALL IBWRT(SD375%, "31474846FF")               'M1, STOP, ERASE, START
T1! = TIMER    'starts the cycle timer here
'----------------------------------------------------------------
'This routine is accomplished while the SD 375 is conducting its next
'average
'----------------------------------------------------------------
FOR I = 1 TO 10
 First% = 8 * (Cell(I) - 1) + 3            'beginning of bytes for
cell(I)
 CellString$ = MID$(PrecisionData, First%, 8)
 'Compute BYTES 1 and 2
 FOR J = 1 TO 2
   K = 2 * J - 1
   H1$ = MID$(CellString$, K, 1)
   H2$ = MID$(CellString$, K + 1, 1)
   IF H1$ < "A" THEN D1% = ASC(H1$) - 48 ELSE D1% = ASC(H1$) - 55
```

```
   IF H2$ < "A" THEN D2% = ASC(H2$) - 48 ELSE D2% = ASC(H2$) - 55
   Byte%(J) = D1% * 16 + D2%
 NEXT J
 'BYTE 3 is always zero
 'Compute BYTE 4
   H1$ = MID$(CellString$, 7, 1)
   H2$ = MID$(CellString$, 8, 1)
   IF H1$ < "A" THEN D1% = ASC(H1$) - 48 ELSE D1% = ASC(H1$) - 55
   IF H2$ < "A" THEN D2% = ASC(H2$) - 48 ELSE D2% = ASC(H2$) - 55
   Byte%(4) = D1% * 16 + D2%
   Real!(I)=MakeReal!(Byte%(1),Byte%(2),Byte%(4))/451'for hanning window
   LOCATE 13 + I, 1
   Log10!(I) = LOG(Real!(I)) / LOG(10#)
   PRINT I; TAB(10); Real!(I); TAB(26); " Volts     "; : COLOR 9, 0
   PRINT 10 * Log10!(I); TAB(48); "dB        ": COLOR 14, 0
NEXT I
LOCATE 1, 1: PRINT SPACE$(3); "...writing to files."; SPACE$(30)
'put first 5 values in channel A file, second 5 in Channel B file
   ChA.Fre 1 = Real!(1):          ChB.Freq1 = Real!(6)
   ChA.Freq2 = Real!(2):          ChB.Freq2 = Real!(7)
   ChA.Freq3 = Real!(3):          ChB.Freq3 = Real!(8)
   ChA.Freq4 = Real!(4):          ChB.Freq4 = Real!(9)
   ChA.Freq5 = Real!(5):          ChB.Freq5 = Real!(10)
   ChA.Time0 = SampleTime$:       ChB.Time0 = SampleTime$
   ChA.DataDate = DataDate$:      ChB.DataDate = DataDate$
'write to file
RecordNumber2 = RecordNumber2 + 1
RecordNumber3 = RecordNumber3 + 1
PUT #2, RecordNumber2, ChA
PUT #3, RecordNumber3, ChB
WRITE #5, MID$(PrecisionData,3,3200) 'seq file for raw ch A data
WRITE #6, MID$(PrecisionData, 3203, 3200) 'raw data for Ch B
LOCATE 1, 1: PRINT "...writing completed.                    "
END SUB

SUB AskIfPrintoutWanted
CLS : LOCATE 12, 20
INPUT "Do you want a printout of the data files (y/n)? ", A$
DO WHILE UCASE$(A$) <> "Y" AND UCASE$(A$) <> "N"
 LOCATE 12, 20
 INPUT "Do you want a printout of the data files (y/n)? ", A$
LOOP
CLOSE #1: CLOSE #2: CLOSE #3
IF UCASE$(A$) = "Y" THEN CALL PrintFiles
END SUB


DEFINT A-Z
SUB PrintFiles
SHARED ChA AS RecordType1, ChB AS RecordType1
SHARED Spectrum AS RecordType2, Volt(), Level()
```

```
OPEN "ChanA.dat" FOR RANDOM ACCESS READ AS #2 LEN = LEN(ChA)
OPEN "ChanB.dat" FOR RANDOM ACCESS READ AS #3 LEN = LEN(ChB)
OPEN "Voltage.DAT" FOR RANDOM ACCESS READ AS #1 LEN = LEN(ChA)
NumberOfRecords1=LOF(1)/LEN(Spectrum) 'Determines # records in each file
NumberOfRecords2=LOF(2)/LEN(ChA)      'so that existing files will not
NumberOfRecords3=LOF(3)/LEN(ChB)      'be written over later.
LOCATE 7,1:PRINT "Number Of Records in Spectra.DAT is ";NumberOfRecords1
T$ = "   DATE    VCR   TIME      40 Hz    100 Hz   315 Hz  1000 Hz  1500
Hz"
L$="---------- --- -------- --------  -------- -------- --------
--------"
'      MM-DD-YYYY #-A HH:MM:SS #.###### #.###### #.###### #.######
#.######
'**** Print Spectra.DAT file ****************************************
PRINT #4,"Spectra.DAT data file ";"current time is ";TIME$; " ";DATE$
FOR RecordNumber = 1 TO RecordNumber1
 GET #1, RecordNumber, Spectrum
 Volt(RecordNumber) = Spectrum.Voltage
 Level(RecordNumber) = Spectrum.Level
NEXT RecordNumber
U$ = "####  #.######^^^^  ###.##        ####  #.######^^^^  ###.##"
FOR I = 1 TO 50   'print to screeen until tested
 J = I + 50
 PRINT USING U$; 5 * I; Volt(I); Level(I); 5 * (J); Volt(J); Level(J)
NEXT I
PRINT CHR$(12)
FOR I = 101 TO 150
 J = I + 50
 PRINT USING U$; 5 * I; Volt(I); Level(I); 5 * (J); Volt(J); Level(J)
NEXT I
FOR I = 201 TO 250
 J = I + 50
 PRINT USING U$; 5 * I; Volt(I); Level(I); 5 * (J); Volt(J); Level(J)
NEXT I
PRINT CHR$(12)
FOR I = 301 TO 350
 J = I + 50
 PRINT USING U$; 5 * I; Volt(I); Level(I); 5 * (J); Volt(J); Level(J)
NEXT I
PRINT CHR$(12)
Goto bypass:
'*********** Print Channel A data file ****************************
PRINT #4, "Channel A File data": PRINT #4, T$: PRINT #4, L$
FOR RecordNumber = 1 TO NumberOfRecords2
 GET #2, RecordNumber, ChA
 PRINT #4, ChA.DataDate; " "; ChA.ChannelID; " "; ChA.Time0; " ";
 PRINT #4, USING " #.######^^^^"; ChA.Freq1; ChA.Freq2; ChA.Freq3;
ChA.Freq4'; ChA.Freq5
NEXT RecordNumber
PRINT #4, CHR$(12) 'form feed
'************** Print Channel B data file ********************************
PRINT #4, "Channel B File data": PRINT #4, T$: PRINT #4, L$
```

```
FOR RecordNumber = 1 TO NumberOfRecords3
 GET #3, RecordNumber, ChB
 PRINT #4, ChB.DataDate; ChB.ChannelID; " "; ChB.Time0; " ";
 PRINT #4, USING " #.######^^^^"; ChB.Freq1; ChB.Freq2; ChA.Freq3;
ChB.Freq4'; ChB.Freq5
NEXT RecordNumber
Bypass:
END SUB

SUB CheckStatus
SHARED SD375%, Averaging%()
 CALL IBSAD(SD375%, 115)
 CALL IBWRT(SD375%, "MST(B)/" + CHR$(13))
 CALL IBSAD(SD375%, 111)      'SD 375 must be in BINARY Byte coding
 CALL IBRDI(SD375%, Averaging%(), 2)    '"1" if avg in progress (p.4-23)
 TO! = TIMER: Delay! = 0!
 DO UNTIL Delay! > .4       'Waits .4 SEC before next status check
    Delay! = TIMER - TO!
 LOOP
END SUB

SUB ConvertRawData
SHARED Spectrum AS RecordType2, RawData AS STRING * 3200
SHARED File1$  Sample%
'*** check to see if random access file already exists ****
CLS: PRINT "Already have random file to break up (Y/N)?": A$ = INPUT$(1)
IF UCASE$(A$) = "Y" GOTO StopHere '*** skip file creation if 'yes' ***
'** get name of ASCII input file (created by SD 375 transfer process)
INPUT "Complete name of input file (FILENAME.EXT)?", InputFile$
PRINT "If input file does not exist this program will hang up."
LOCATE 12, 20
PRINT "Enter [A] to abort or [C] to continue.": A$ = INPUT$(1)
'*** test for correct response ***
DO WHILE UCASE$(A$) <> "A" AND UCASE$(A$) <> "C"
  LOCATE 12, 20: BEEP: BEEP
  PRINT "Enter [A] to abort or [C] to continue.": A$ = INPUT$(1)
LOOP
IF UCASE$(A$) = "A" THEN GOTO StopHere: '* abort program if "A" entered
'* convert ASCII file to random access file *
CLS : LOCATE 12, 20: PRINT "Converting data..."
OPEN InputFile$ FOR INPUT AS #10
OPEN "SPECTRA.DAT" FOR RANDOM ACCESS WRITE AS #17 LEN = LEN(Spectrum)
'* SPECTRA.DAT is final product (used to create additional file later) *
RecordNumber = 0
DO UNTIL EOF(10)
 INPUT #10, RawData '* read 1 string of ASCII HEX data (400 groups of 8)
  FOR I = 1 TO 400  '250 stops at 1250 Hz (there are 400 total for 2KHz)
  First% = 8 * (I - 1) + 1         'beginning of bytes for cell I
  CellString$ = MID$(RawData, First%, 8)
  '** Compute BYTES 1 and 2 **
  FOR J = 1 TO 2
    K = 2 * J - 1
```

```
    H1$ = MID$(CellString$, K, 1)
    H2$ = MID$(CellString$, K + 1, 1)
    IF H1$ < "A" THEN D1% = ASC(H1$) - 48 ELSE D1% = ASC(H1$) - 55
    IF H2$ < "A" THEN D2% = ASC(H2$) - 48 ELSE D2% = ASC(H2$) - 55
    Byte%(J) = D1% * 16 + D2%
  NEXT J
  '** BYTE 3 is always zero **
  '** Compute BYTE 4 **
    H1$ = MID$(CellString$, 7, 1)
    H2$ = MID$(CellString$, 8, 1)
    IF H1$ < "A" THEN D1% = ASC(H1$) - 48 ELSE D1% = ASC(H1$) - 55
    IF H2$ < "A" THEN D2% = ASC(H2$) - 48 ELSE D2% = ASC(H2$) - 55
    Byte%(4) = D1% * 16 + D2%
    FSV=1 'Full Scale Value for SD375 (=1 7/27/87 data,=2 7/28/87 data)
    Spectrum.Voltage = FSV * (MakeReal!(Byte%(1),Byte%(2),Byte%(4))/451)
    Spectrum.Freq = 5 * I  'volts/451 removes gain from Hanning window
    Spectrum.Level = 10 * LOG(Spectrum.Voltage) / LOG(10#) ' MAG. not
POWER
    RecordNumber = RecordNumber + 1
    PUT #17, RecordNumber, Spectrum
 NEXT I
LOOP
CLOSE #15: CLOSE #16: CLOSE #17 '*** close all open files ***
PRINT "Do you want to continue? (Y/N) ": A$ = INPUT$(1)
IF UCASE$(A$) = "N" THEN GOTO EndProg
StopHere:
'*** get source filename (created above) for creation of small files ***
INPUT "Enter name of random Input file (file MUST exist): ", InputFile$
OPEN InputFile$ FOR RANDOM ACCESS READ AS #7 LEN = LEN(Spectrum)
NumberOfSamples = (LOF(7) \ LEN(Spectrum)) \ 400  '250 is for 1250 Hz
MakeChoice:
CLS : COLOR 14, 0: LOCATE 10, 15
PRINT "Number of samples in "; InputFile$; " is "; NumberOfSamples
LOCATE 12, 15 ' *** separate file for each sample ***
PRINT "If you want to make one-sample spectra files, press [A]"
LOCATE 13, 15 ' *** separate file for each frequency ***
PRINT "If you want to make single-frequency files,   press [B]"
LOCATE 16, 15
PRINT "Enter your choice [A], [B], or [E] to exit.": A$ =
UCASE$(INPUT$(1))
COLOR 9, 0
SELECT CASE A$
CASE "A"          '****** CREATE A SEPARATE FILE FOR EACH SAMPLE ******
   Sample% = 1

  DO
    CLS : LOCATE 1, 15:
    INPUT "Enter full name of output file for magnitude: ", File1$
    LOCATE 14, 15 : INPUT "Enter sample number:", Sample%
    First = 400 * (Sample% - 1) + 1
    OPEN File1$ FOR OUTPUT AS #8
    VariableName$ = LEFT$(File1$, 3)
```

```
    PRINT #8, VariableName$
    FOR I = First TO First + 399   '249 FOR 1250 HZ
      GET #7, I, Spectrum
      PRINT #8, Spectrum.Voltage
    NEXT I
    CLOSE #8
    LOCATE 16, 15
    PRINT "Do you want to make another file? (Y/N) ": Q$ = INPUT$(1)
    Sample% = Sample% + 1
  LOOP UNTIL Sample% > NumberOfSamples     '   UCASE$(Q$) = "N"
CASE "B" ' ****** CREATE A SEPARATE FILE FOR EACH FREQUENCY ******
  DO
    CLS : LOCATE 10, 1:
    INPUT "Enter name of output file for magnitude:", F$
    LOCATE 14, 10: COLOR 9, 0
    DO
      INPUT "Enter frequency (MULTIPLE OF 5, 5 =< F <= 2000): ", F%
      CLS : LOCATE 14, 10: COLOR 14, 0
      PRINT "Frequency entered is "; F%; " Hz. Is this correct? (Y/N) "
      A$ = INPUT$(1)
      IF UCASE$(A$) = "N" THEN
        INPUT "Enter frequency (MULTIPLE OF 5, 5 =< F <= 2000):", F%
      END IF
    LOOP UNTIL UCASE$(A$) = "Y"
    COLOR 9, 0  'blue on black
    S% = 0 'keeps track of sample number
    Bin% = F% \ 5       'bin number of each sample
    OPEN F$ FOR OUTPUT AS #8
    FOR I = 1 TO NumberOfSamples
      Record% = (I - 1) * 400 + Bin%
      GET #7, Record%, Spectrum
      PRINT #8, Spectrum.Voltage
    NEXT I
    CLOSE #8
    LOCATE 16, 15: COLOR 14, 4: 'yellow on red
    PRINT "Do you want to make another file? (Y/N) ": Q$ = INPUT$(1)
    COLOR 14, 0      'yellow on black
    PRINT "Number of values in file is "; NumberOfSamples
  LOOP UNTIL UCASE$(Q$) = "N"
CASE "E": GOTO EndProg
CASE ELSE: BEEP: BEEP: BEEP: GOTO MakeChoice
END SELECT
EndProg:
END SUB

SUB ResetClock
 TIMER OFF
 CLS : COLOR 9, 4
 PRINT "You must enter the current time for the computer system clock."
 COLOR 14, 0
 DO: INPUT "The Hour is (00 - 24) ", Hour$
 LOOP UNTIL VAL(Hour$) >= 0 AND VAL(Hour$) <= 24
```

```
 PRINT
 DO: INPUT "The minutes are (00 - 59)", Minutes$
 LOOP UNTIL VAL(Minutes$) >= 0 AND VAL(Minutes$) <= 59
 PRINT
 DO: INPUT "The seconds are (00 - 59) ", Seconds$
 LOOP UNTIL VAL(Seconds$) >= 0 AND VAL(Seconds$) <= 59
 PRINT
 TIME$ = Hour$ + ":" + Minutes$ + ":" + Seconds$
END SUB

DEFSNG A-Z
FUNCTION MakeReal! (B1%, B2%, B4%)
  MakeReal! = (256 * B1% + B4% - 8192) * (2 ^ (B2% - 128)) / 8192
END FUNCTION
```

APPENDIX B

AMBIENT NOISE LEVEL PLOTS

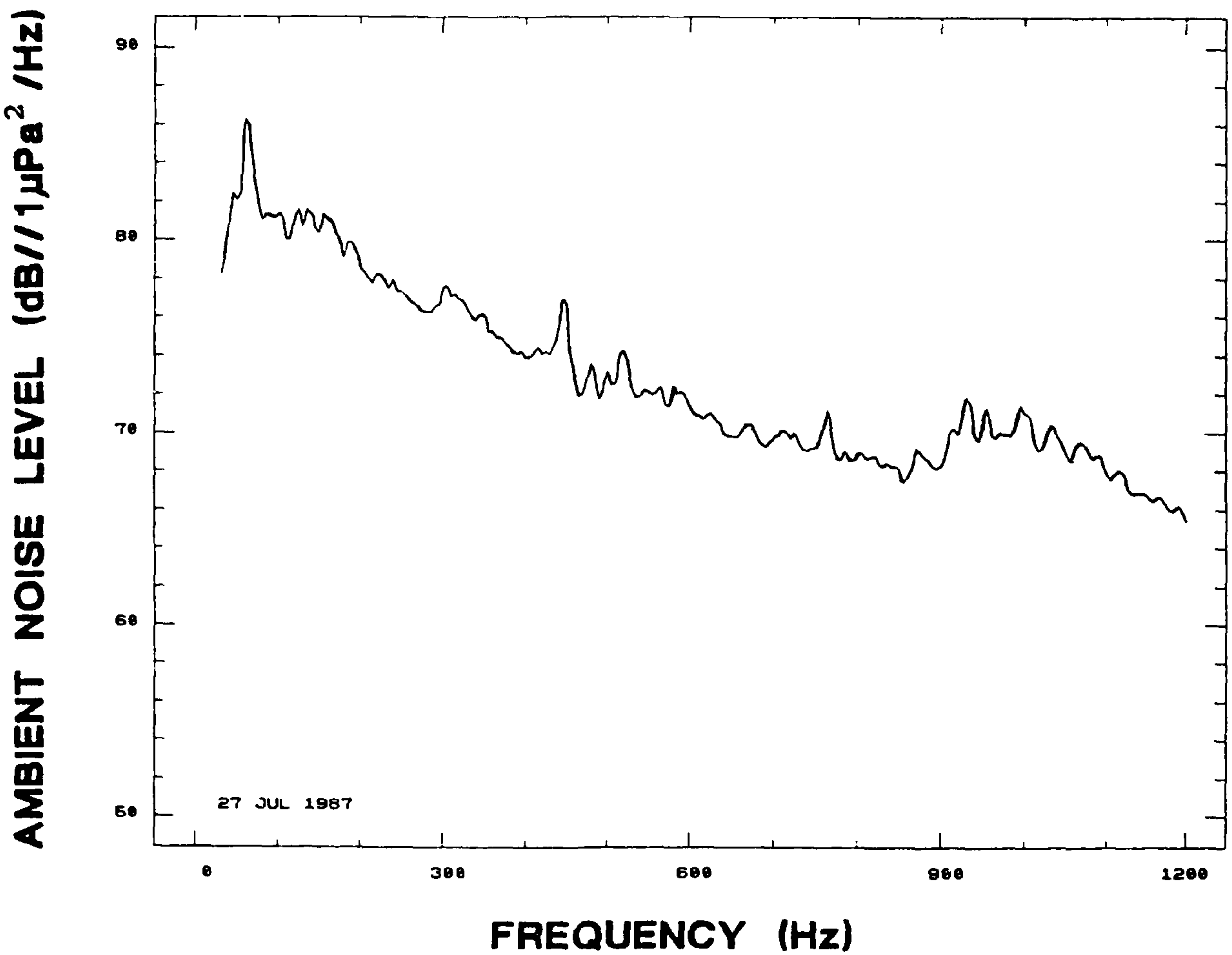


Figure B1. Mean ambient noise level for Buoy 4.

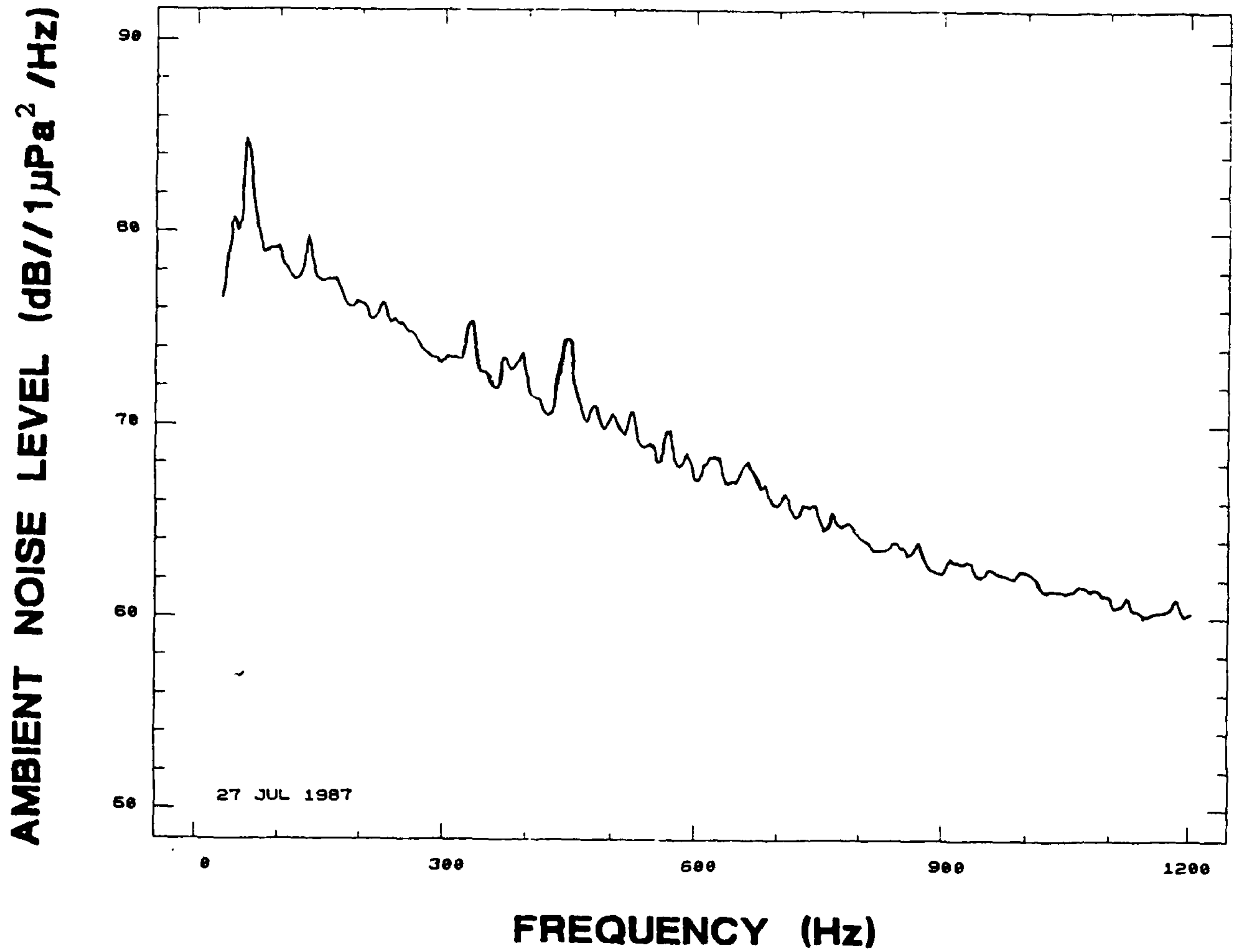


Figure B2. Mean ambient noise level for Buoy 6.

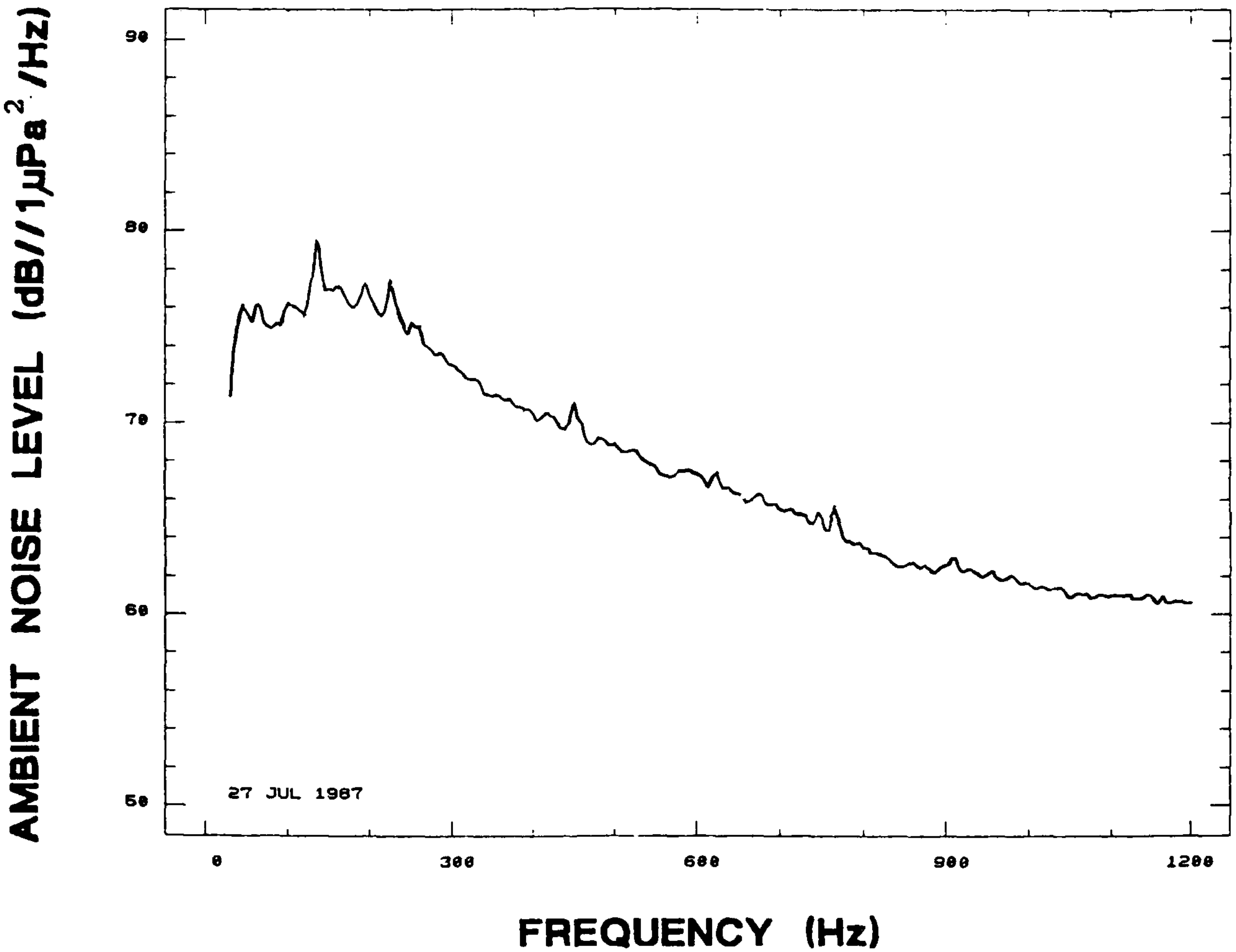


Figure B3. Mean ambient noise level for Buoy 12.

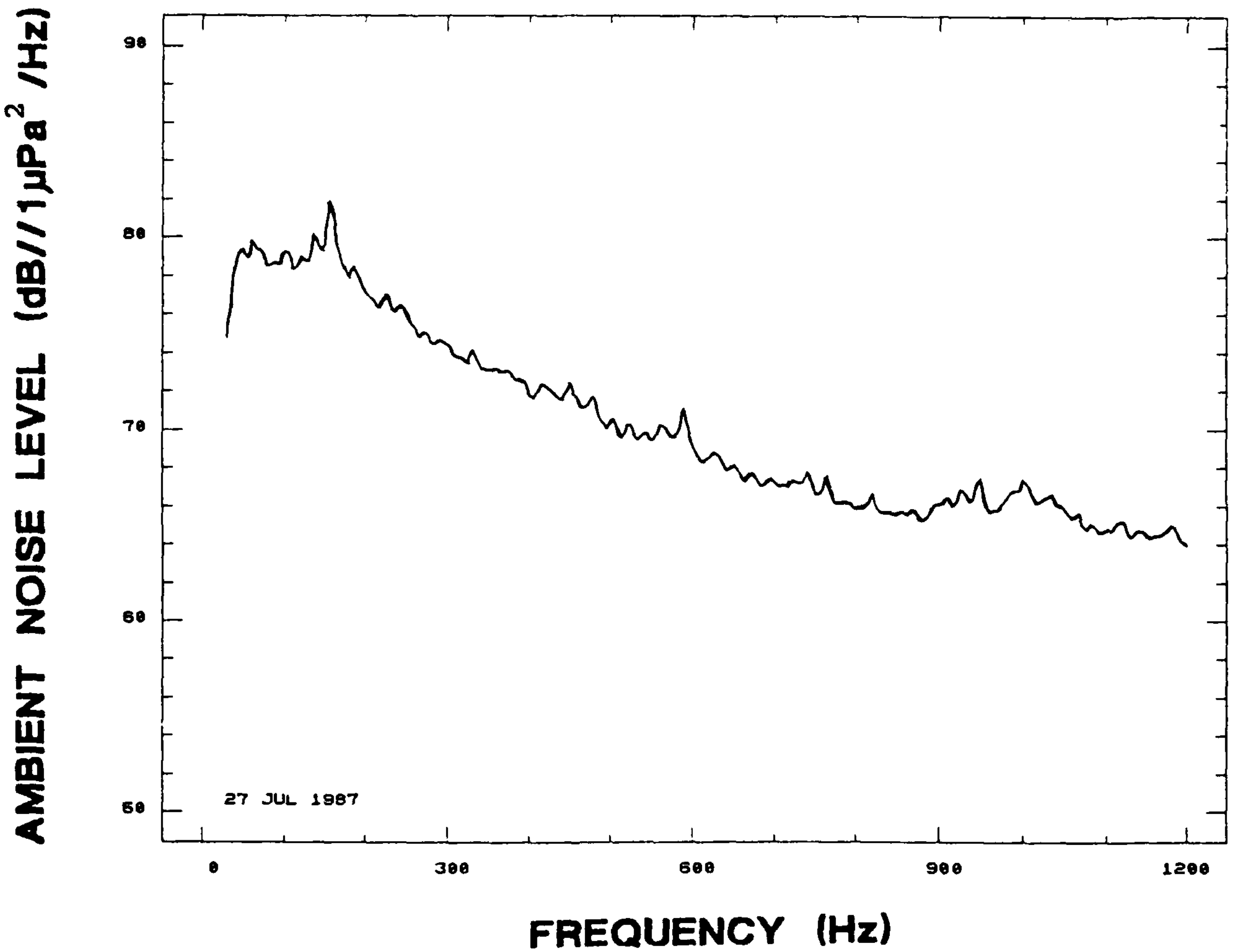


Figure B4. Mean ambient noise level for Buoy 16.

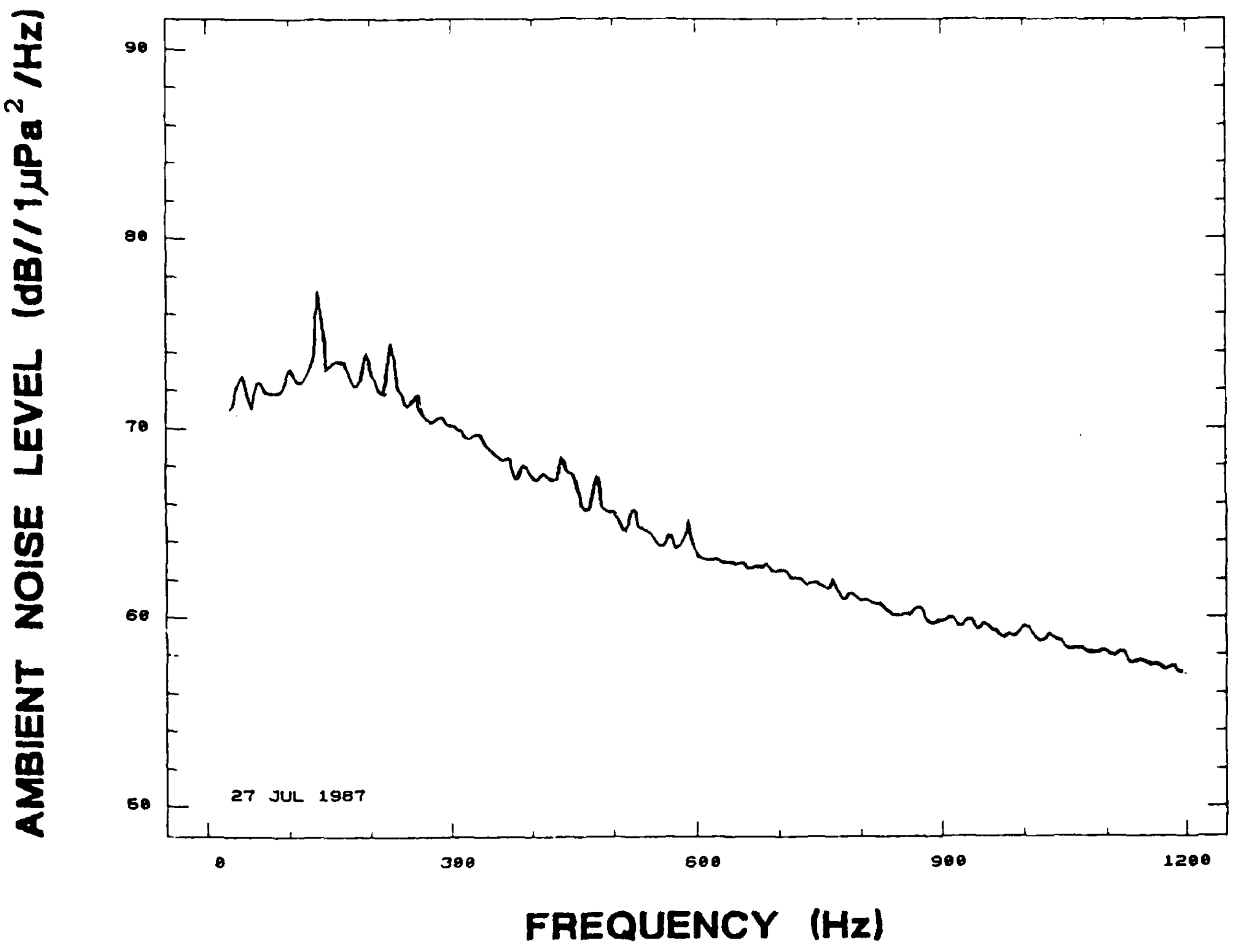


Figure B5. Mean ambient noise level for Buoy 23.

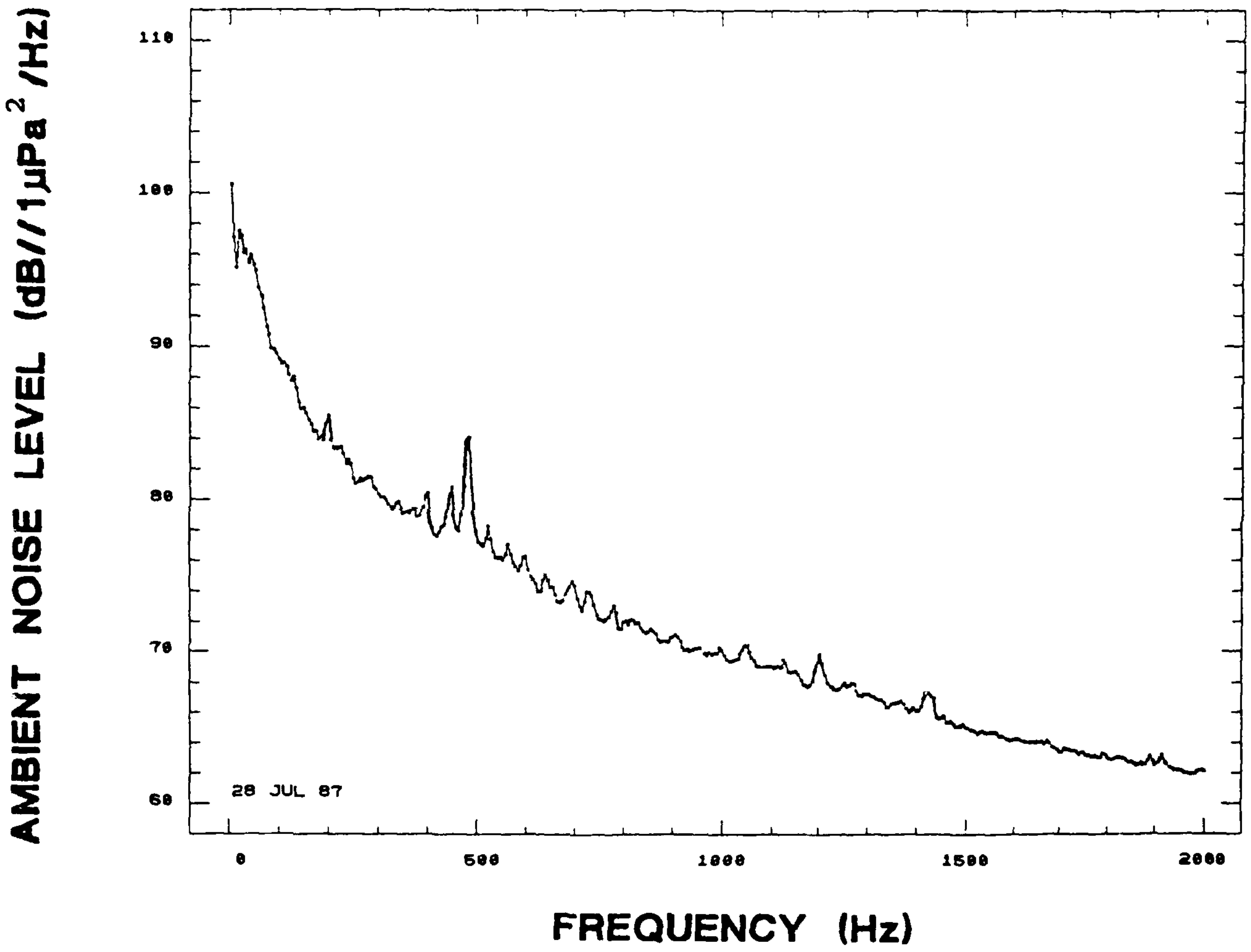


Figure B6. Mean ambient noise level for Buoy 18.

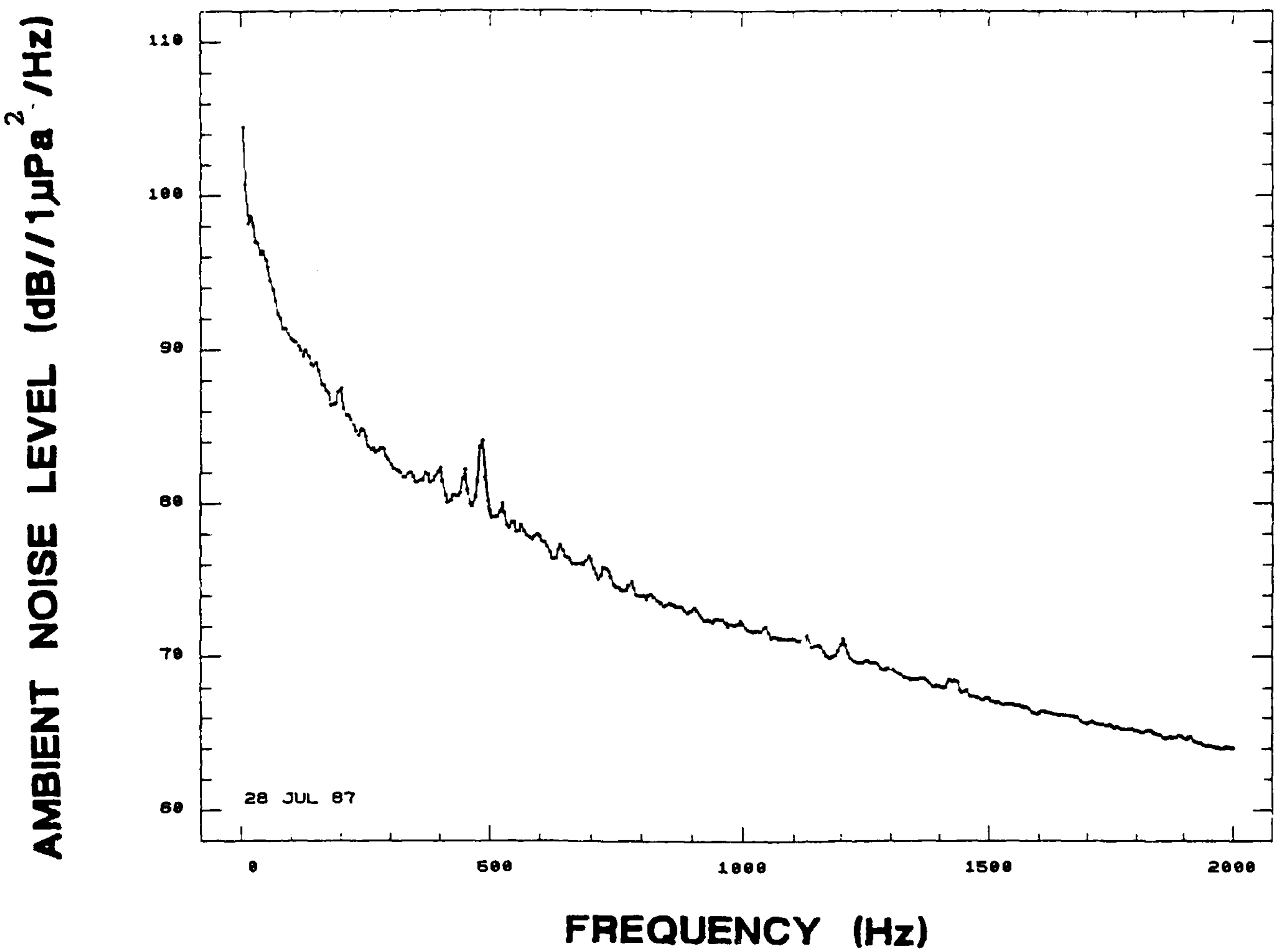


Figure B7. Mean ambient noise level for Buoy 20.

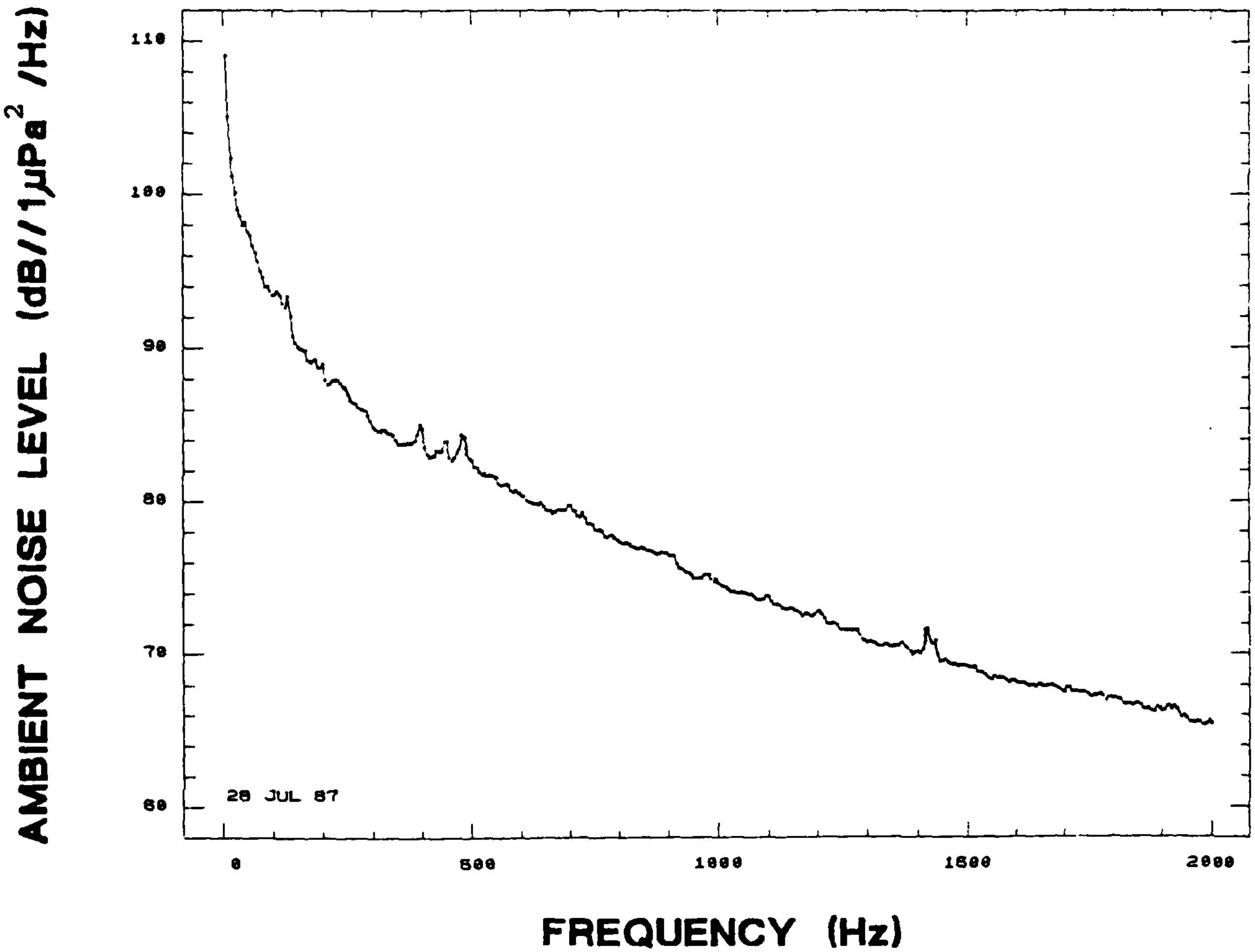


Figure B8. Mean ambient noise level for Buoy 28.

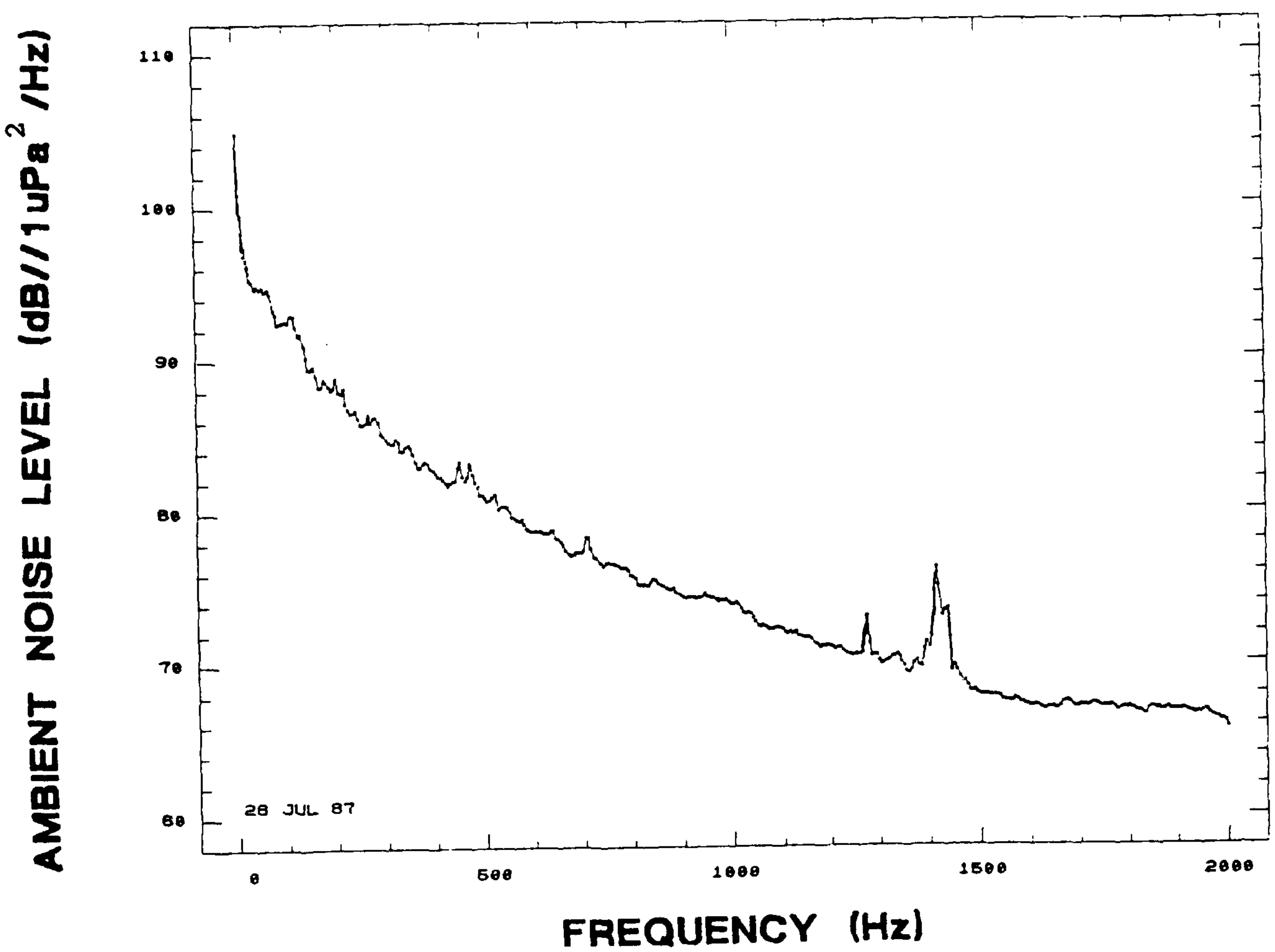


Figure B9. Mean ambient noise level for Buoy 29.

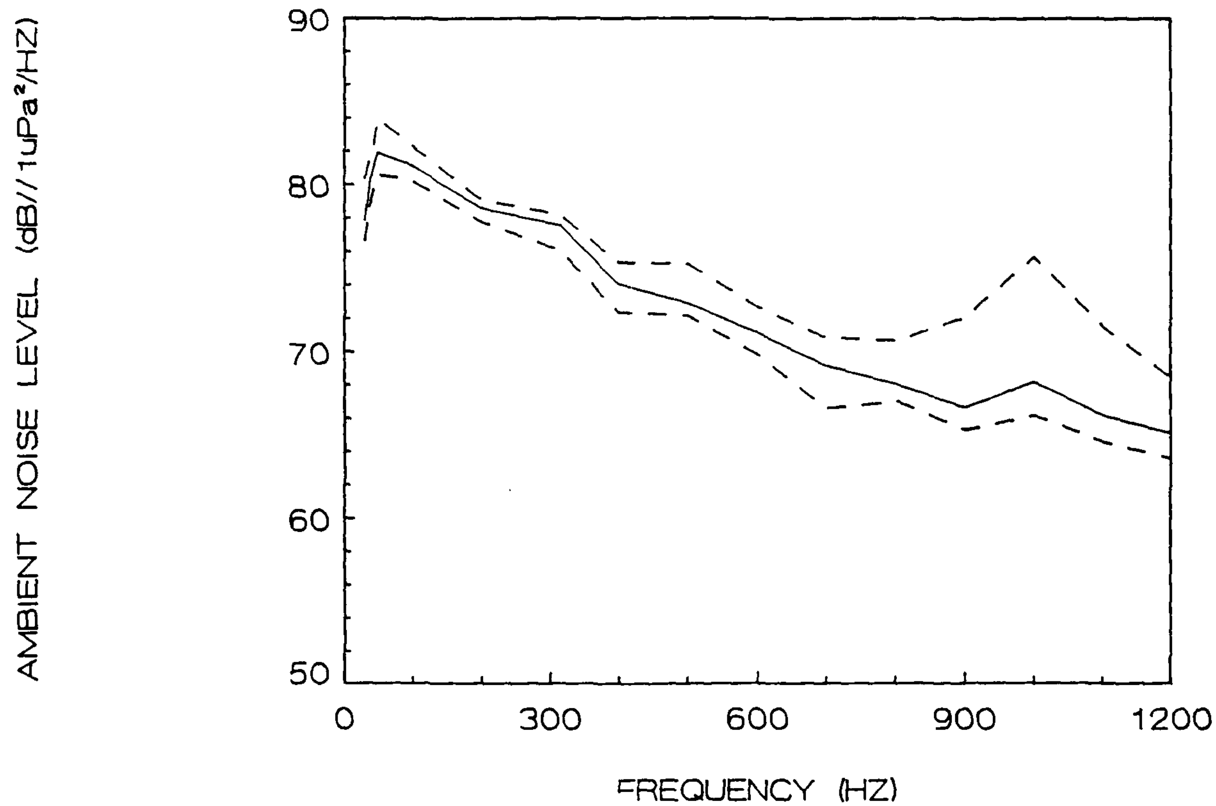


Figure B10. Median ambient noise level for Buoy 4 (7/27/87) bounded by 90th (upper) and 10th (lower) percentiles. 90th percentile shows influence of temporary signal near 1000 Hz.

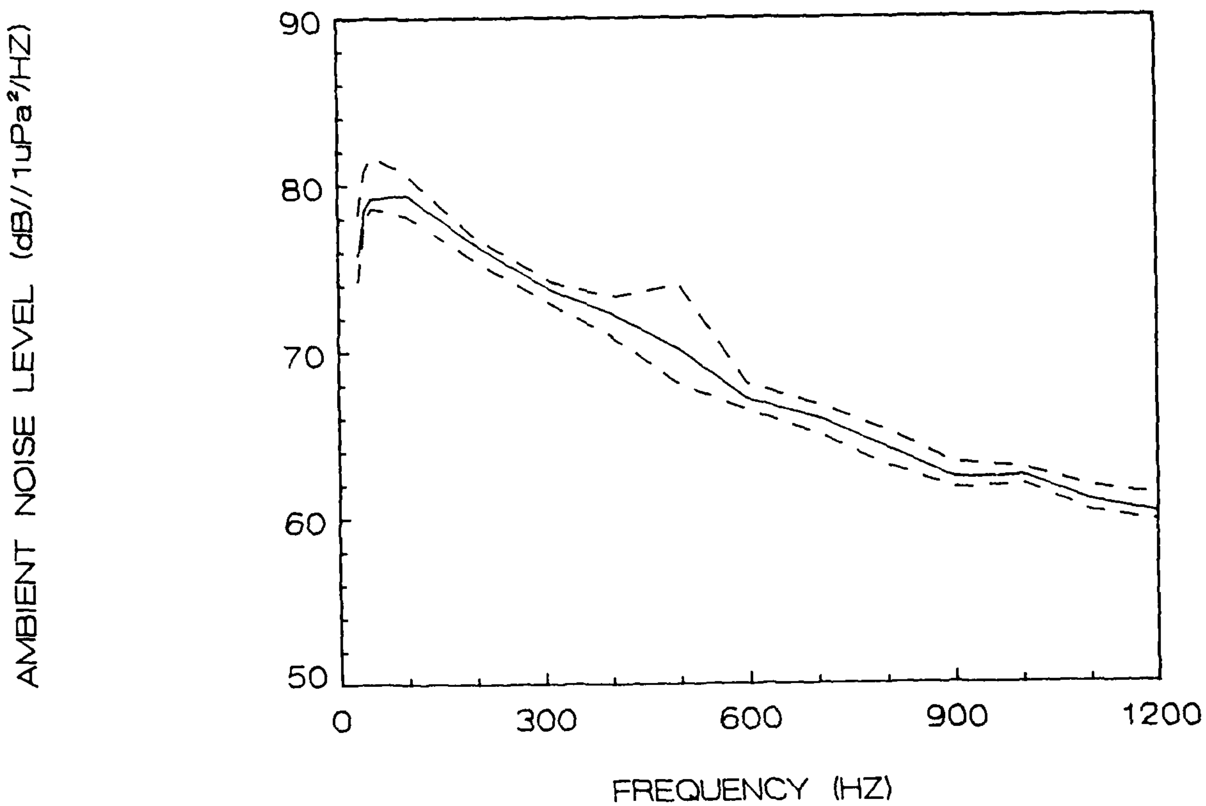


Figure B11. Median ambient noise level for Buoy 6 (7/27/87) bounded by 90th (upper) and 10th (lower) percentiles. 90th percentile shows influence of temporary signal near 450 Hz.

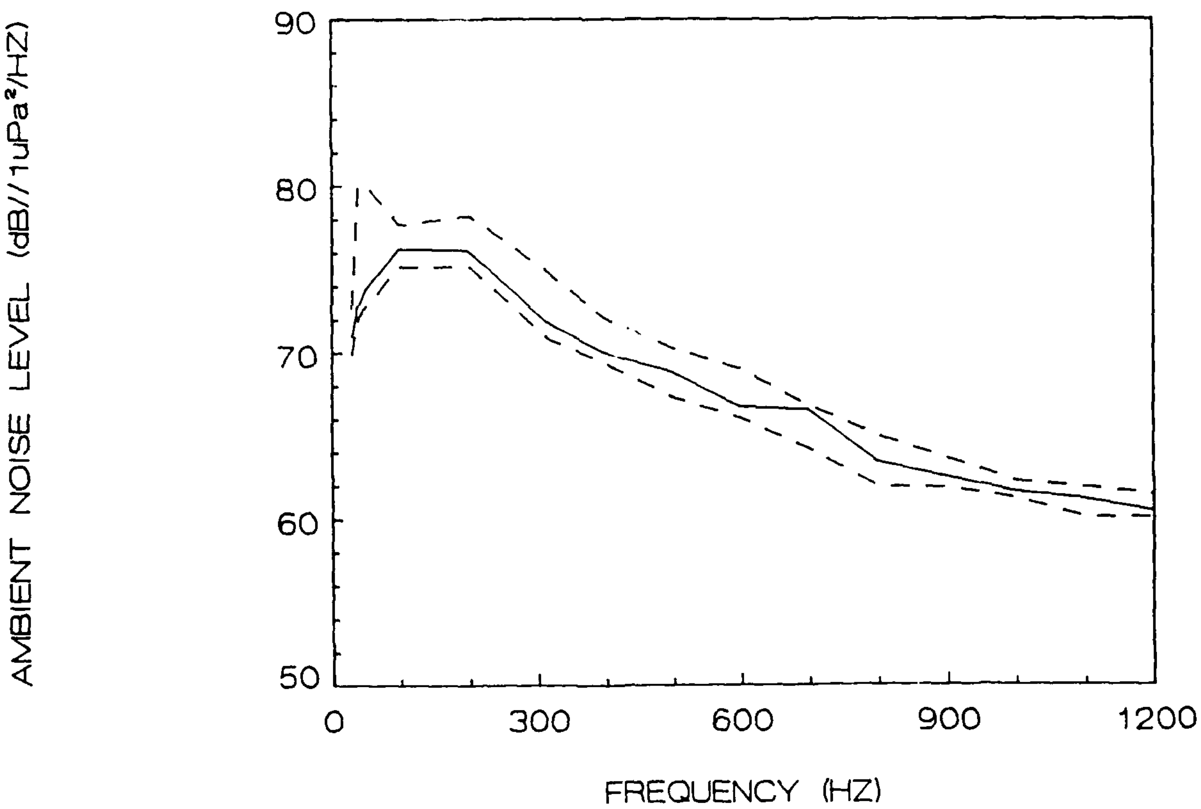


Figure B12. Median ambient noise level for Buoy 12 (7/27/87) bounded by 90th (upper) and 10th (lower) percentiles.

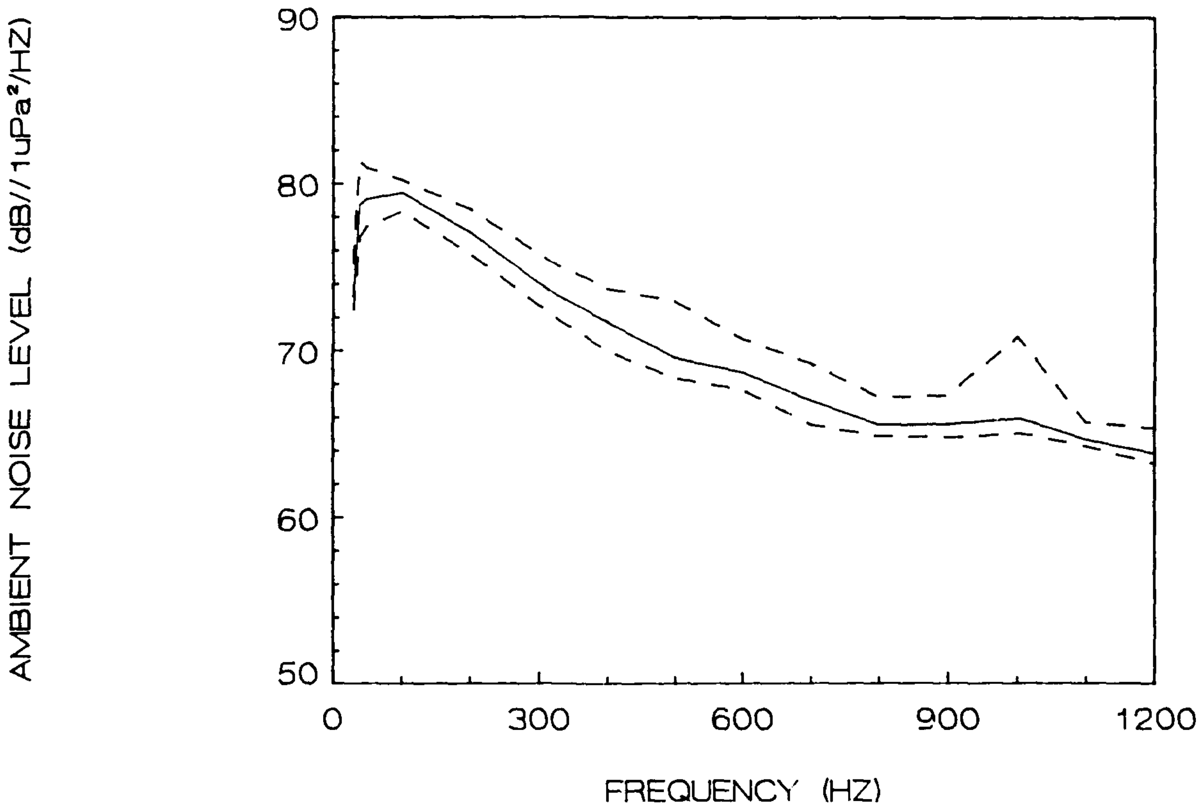


Figure B13. Median ambient noise level for Buoy 16 (7/27/87) bounded by 90th (upper) and 10th (lower) percentiles. 90th percentile shows influence of temporary signal near 1000 Hz.

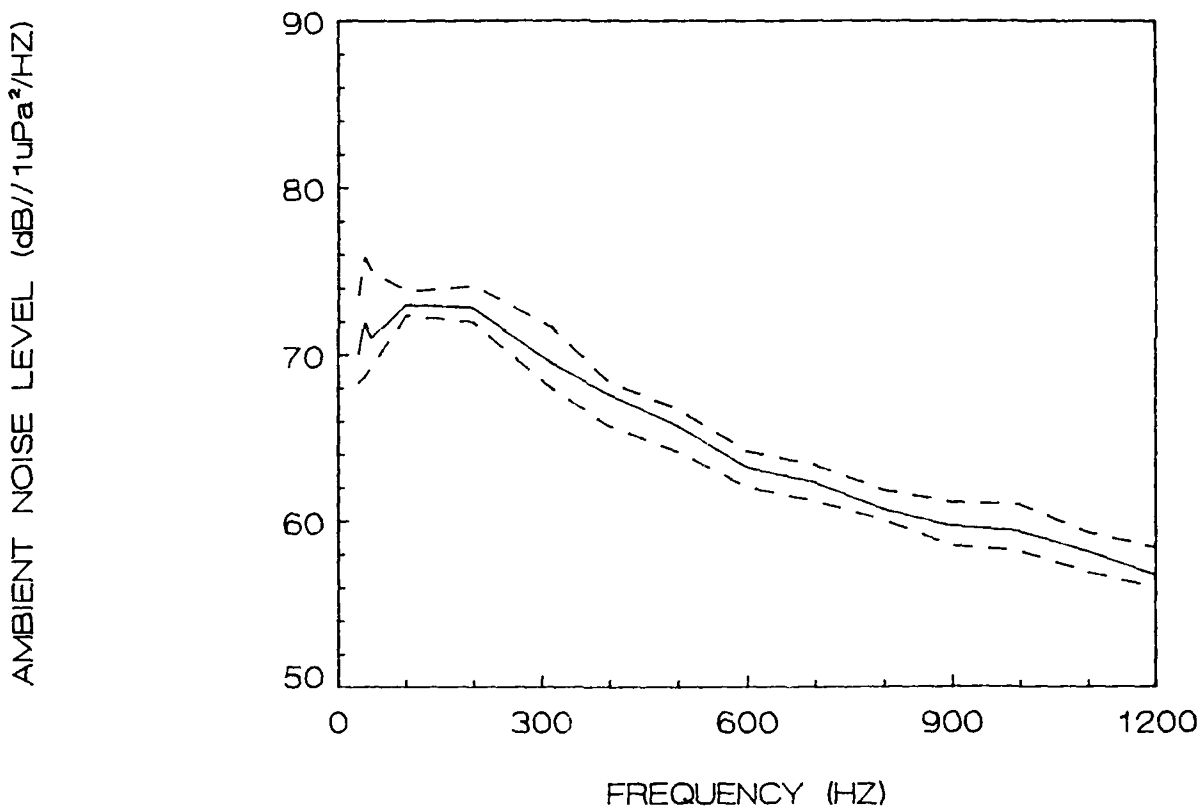
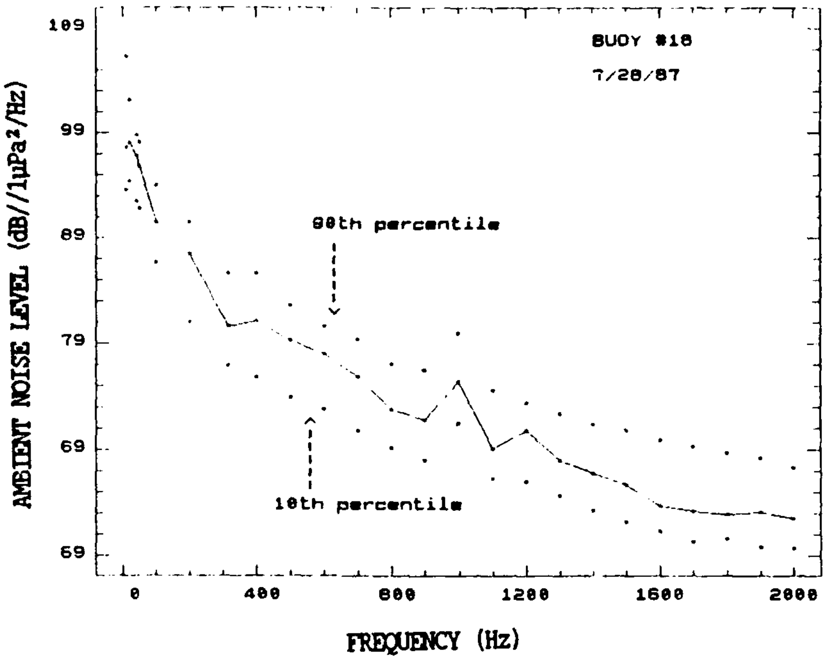


Figure B14. Median ambient noise level for Buoy 23 (7/27/87) bounded by 90th (upper) and 10th (lower) percentiles.

(a)



(b)

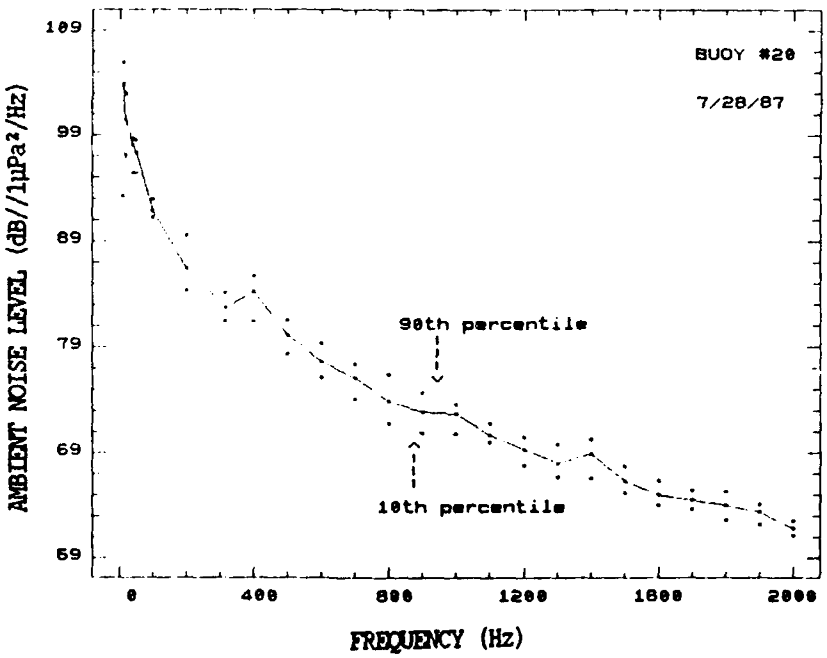
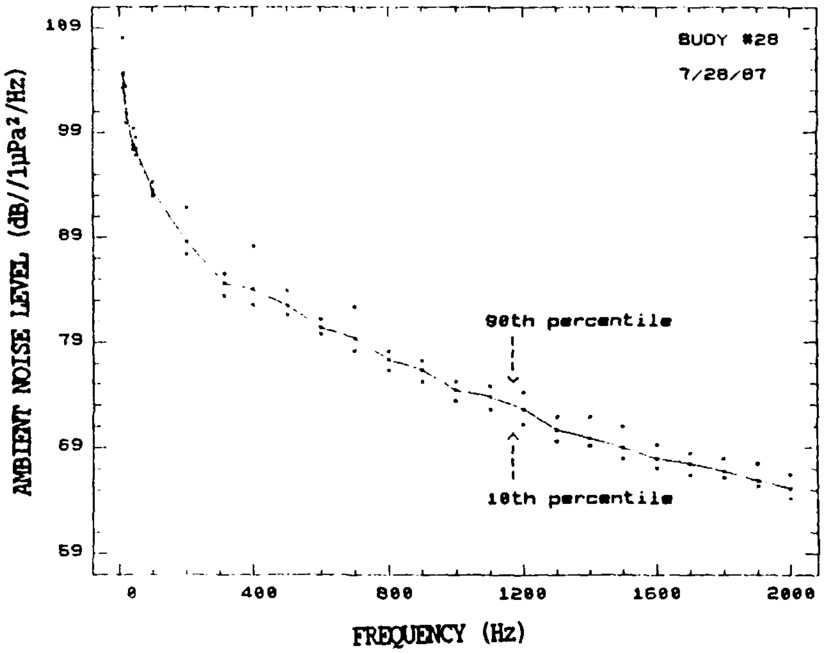


Figure B15. Median ambient noise levels on 28 July for (a) Buoy 18 and (b) Buoy 20.

(a)



(b)

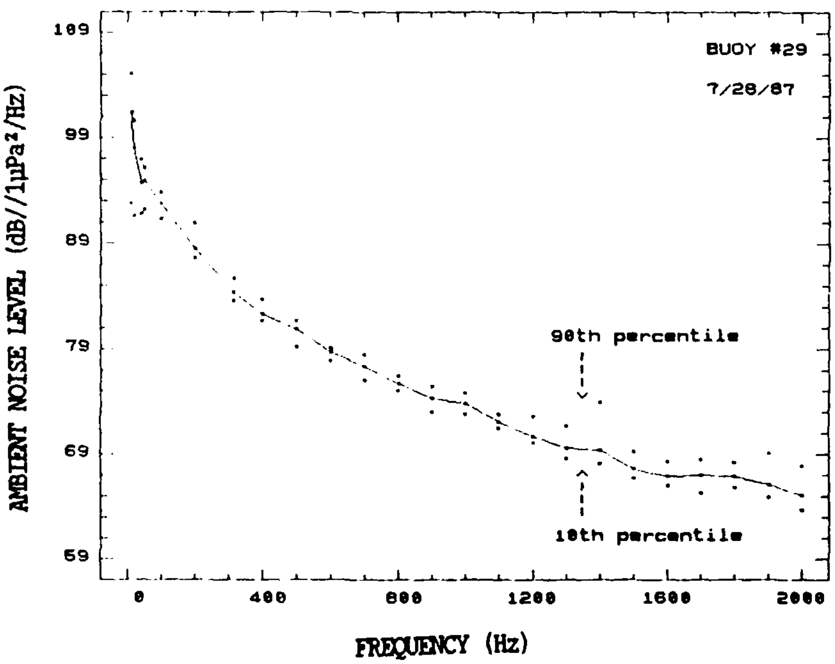


Figure B16. Median ambient noise levels on 28 July for (a) Buoy 28 and (b) Buoy 29.

APPENDIX C

SATELLITE PHOTOS

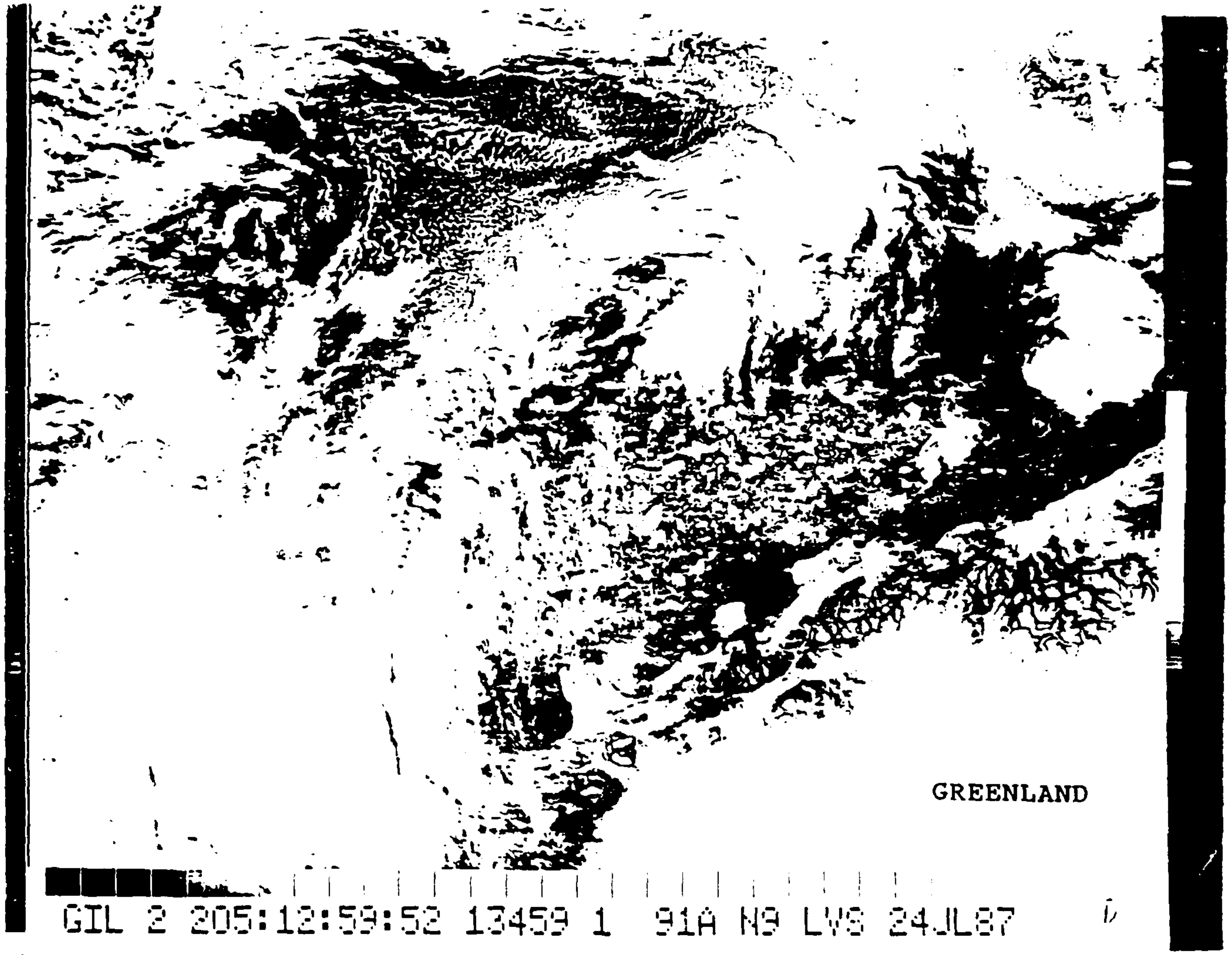


Figure C1. Visual satellite photograph taken at 12:59:52 on 24 July 87.

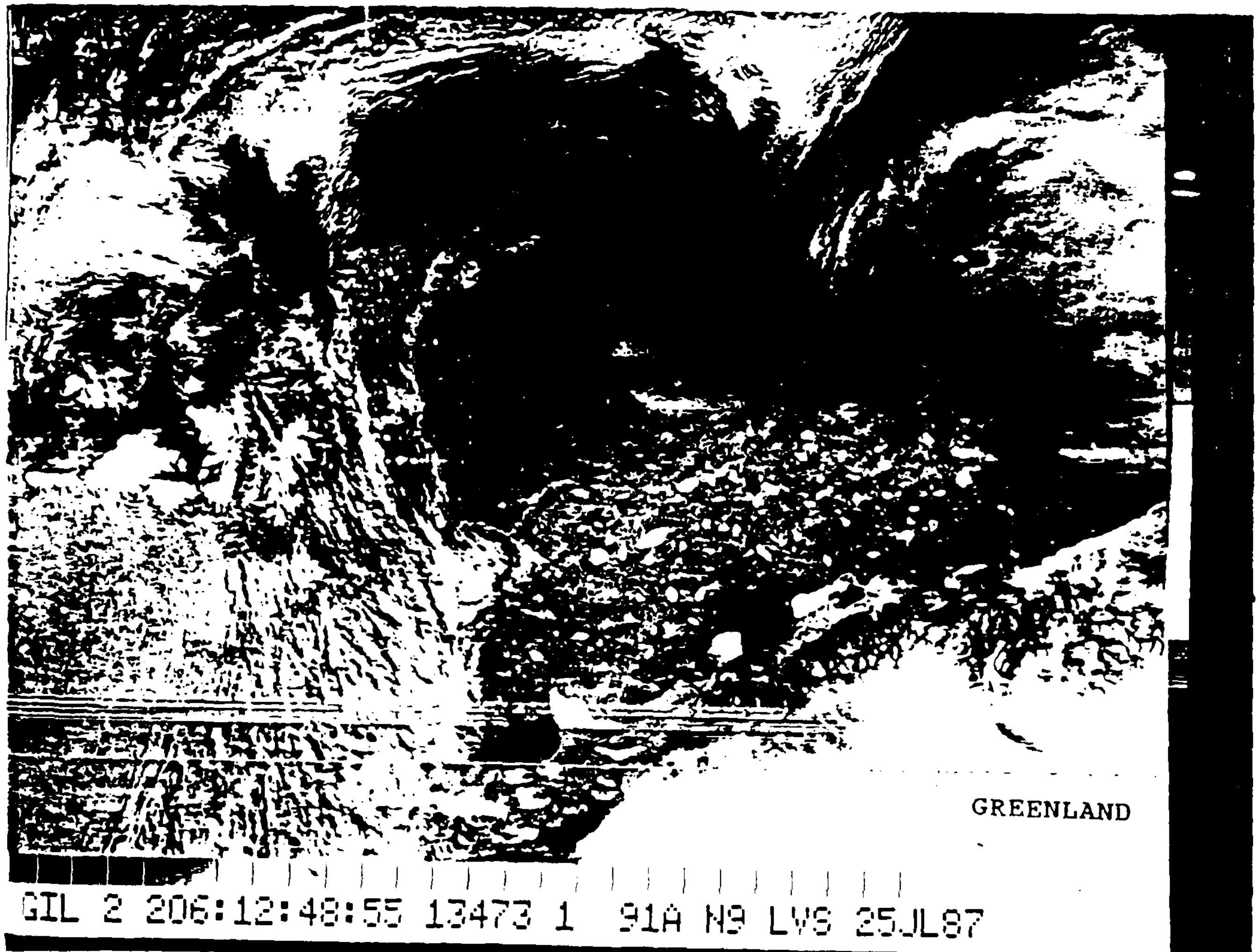


Figure C2. Visual satellite photograph taken at 12:48:55 on 25 July 87.

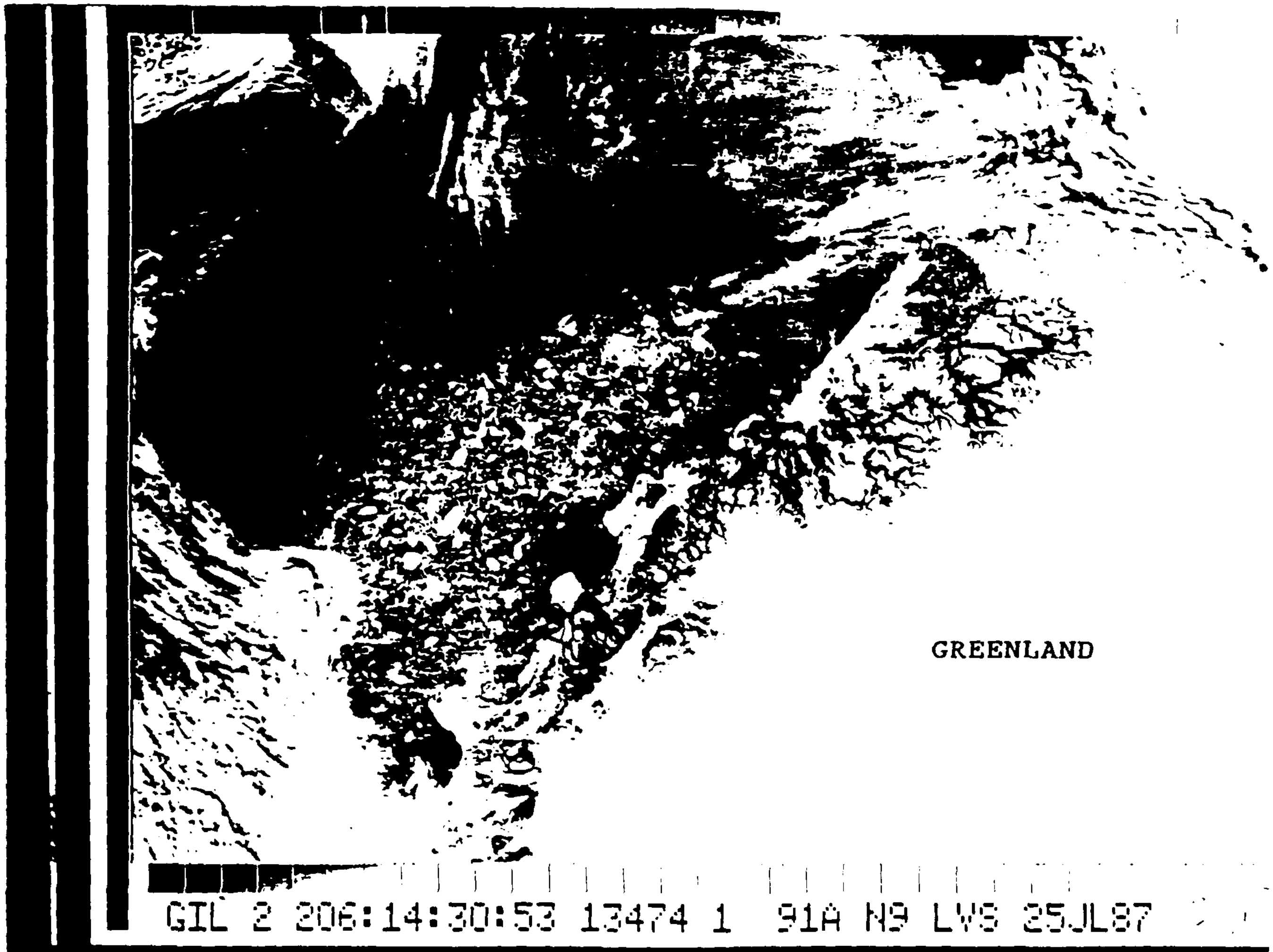


Figure C3. Visual satellite photograph taken at 14:30:53 on 25 July 87.

Figure C4. Visual satellite photograph taken at 14:02:02 on 26 July 87.

Figure C5. Visual satellite photograph taken at 14:02:02 on 26 July 87.

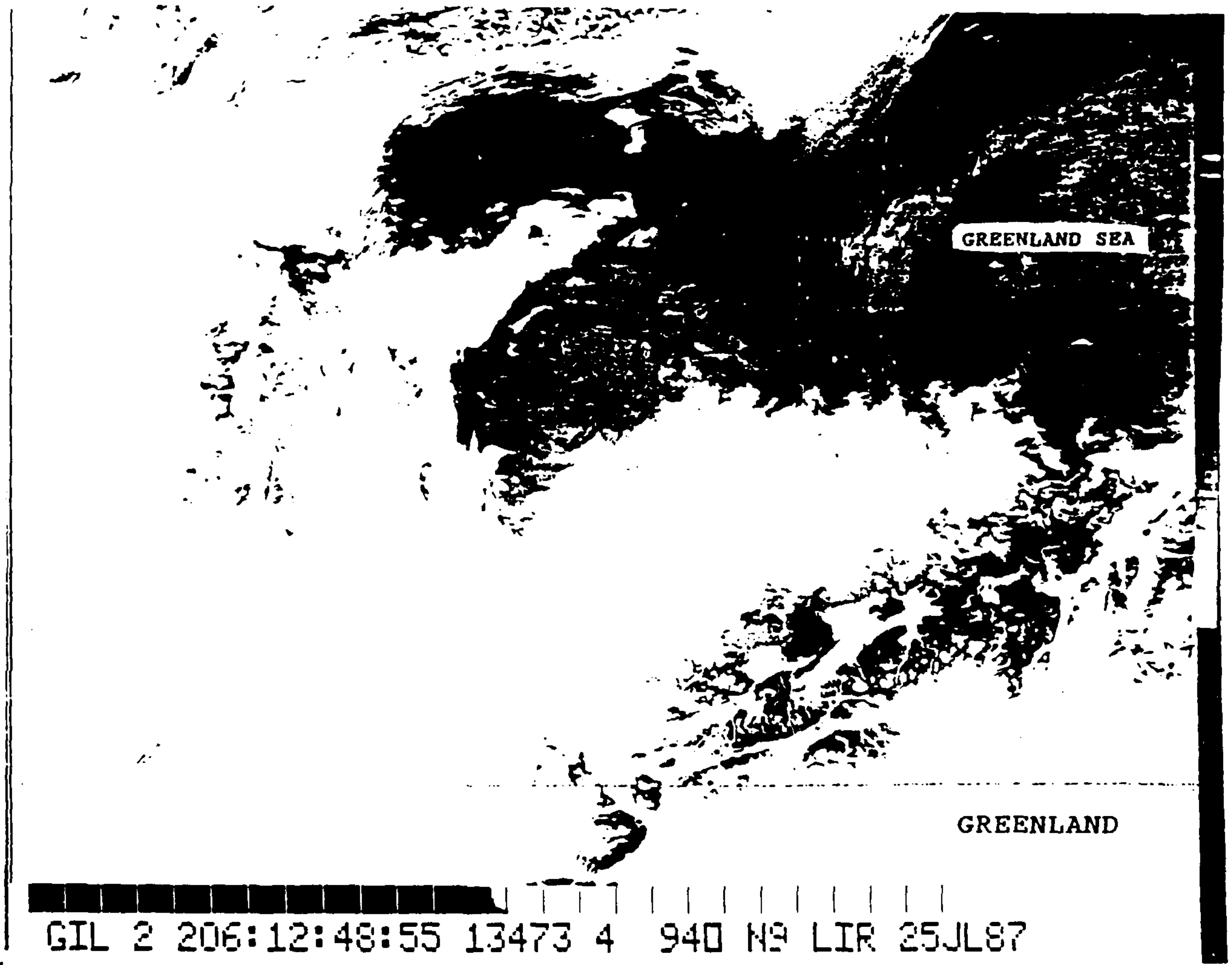


Figure C6. Infrared satellite photograph taken at 12:48:55 on 25 July 87.

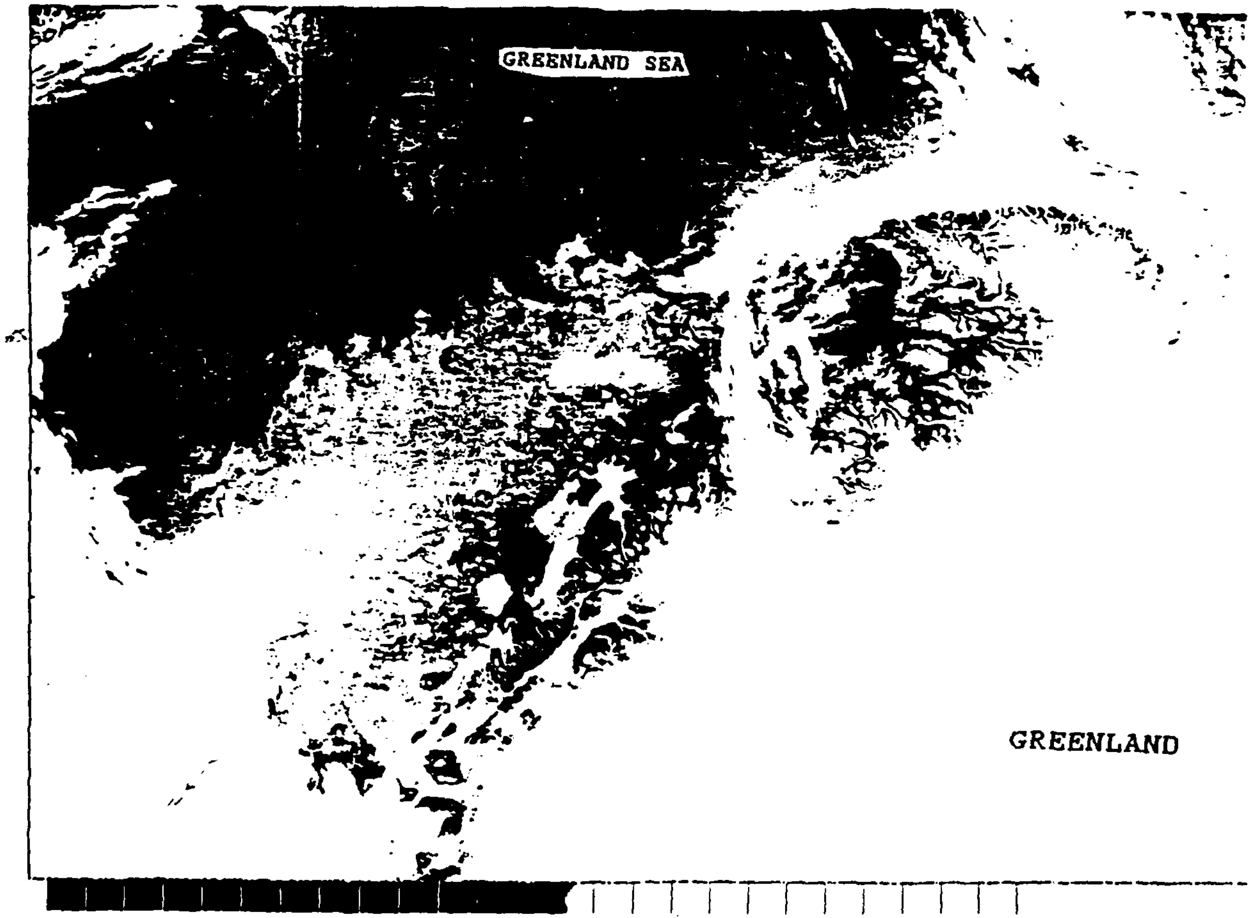


Figure C7. Infrared satellite photograph taken at 14:30:53 on 25 July 87.

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